THE

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OF THE

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THE

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I.—NOTE ON *HALCAMPA CHRYSANTHELLUM*, PEACH.

By ALFRED C. HADDON, M.A., M.R.I.A., Professor of Zoology, Royal College of Science, Dublin.

[Read, November 18, 1885.]

At the corresponding meeting of the Society last year I read a Paper on "A New Species of Halcampa (*H. andresii*), from Malahide," which was printed in the *Proceedings*, n. s., vol. iv., pp. 396–398, pl. xvi., figs. 1–4. Since that date I have, through the kindness of my friends Mr. H. W. Jacob and Mr. G. Y. Dixon, seen several specimens of Halcampa from Malahide, and I find that every one has some variation in colour or marking. This fact has led me to reconsider the characters upon which I based the new species just alluded to, and it has resulted in the opinion that it would be wiser to withdraw that name, and to regard our Dublin specimens as the first known Irish examples of *H. chrysanthellum*, Peach.

While regretting the fact of introducing what I may term a stillborn synonym (especially when coupled with the name of my friend Professor A. Andres), the figures at all events convey a much better idea of the species than the very unsatisfactory ones on plate vii. in Gosse's Monograph, and so far the Paper is not altogether valueless.

In order to substantiate my present view, I propose to give a brief account of all the descriptions we have of *H. chrysanthellum*, together with a short description of the specimens which have passed under my notice. This will, I hope, have the further effect of putting other naturalists on their guard, and of tending to give some idea as to the specific characters of this form.

The following is the bibliography of this species:—

Actinia chrysanthellum, .	Peach, 1847, in Johnston's *Brit. Zooph.*, 2nd ed., p. 220, pl. XXXVII., figs. 10–15.
Edwardsia duodecimcirrata,	Sars, 1851, *Nyt. Mag. for Naturvid.*, vi., p. 142.
,, ,, .	Cocks, 1851, *Rep. R. Cornwall Polytech. Soc.*, ix., p. 6, pl. I., figs. 20, 21.
,, ,, .	Landsborough, 1852, *Pop. Hist. of Brit. Zoophytes.*
Peachia (?), ...	Gosse, 1855, *Trans. Linn. Soc.*, xxi., p. 271.
,, ,, .	Gosse, 1855, *Manual, Marine Zool.*, i., p. 31.
,, ,, .	Milne Edwards, 1857, *Hist. Nat. des Coralliaires*, p. 288.
Halcampa, ...	Gosse, 1858, *Ann. Mag. Nat. Hist.* (3), i., p. 418.
Edwardsia duodecimcirrata,	Danielssen, 1859, *Nyt. Mag. for Naturvid.*, xi., p. 45.
,, ,, .	Lütken, 1860, *Naturhist. Foren. Vidensk. Meddel.*, p. 196.
,, ,, .	Gosse, 1860, *Actinologia Britannica*, p. 247, pl. VII., figs. 9, 10, and woodcut.
,, ,, .	Hincks, 1861, *Ann. Mag. Nat. Hist* (3), viii., p. 363.
Xanthiopus bilateralis, . .	Keferstein, 1863, *Zeitschrift fur wiss. Zool.*, xii., p. 34, pl. II., fig. 22.
Xanthiopus vittatus, . .	Keferstein, 1863, *loc. cit.*, p. 34, pl. II., figs. 15, 16.
Edwardsia duodecimcirrata,	Meyer and Möbius, 1863, *Archiv. für Naturgesch*, p. 70, pl. III. figs. A–D.

Halcampa chrysanthellum,	Dana, 1872, *Corals and Coral Islands,* p. 25, fig. 3.
,, ,, .	Grube, 1873, *Mittheil. über St. Malo und Roscoff u. d. dortige Meeres-besonders; die Annelidenfauna,* p. 38.
,, ,, .	Fischer, 1875, *Nouv. Arch. Mus.,* x., p. 204.
,, ,, .	Andres, 1884, *Fauna und Flora d. Golfes v. Neapel.,* ix., p. 101.
Halcampa kefersteini, . .	Andres, 1884, *ibid.,* p. 102.
Halcampa farinacea, . .	Andres, 1884, in part (not of Verrill), *ibid.,* p. 102.
Halcampa andresii, . .	Haddon, 1885, *Proc. R. Dub. Soc.* (n. s.), iv., p. 396, pl. XVI., figs. 1–4.
Halcampa chrysanthellum,	Pennington, 1885, *British Zoophytes,* p. 175.

Johnston's diagnosis of the species is as follows:—"Body cylindrical, smooth, striped; tentacula twelve, uniserial, sub-marginal, annulated with brown." He quotes the following from Peach's MS.:—"This Actinia I find under stones buried in sand in Fowey Harbour between the tide-marks. Body pale, nearly white, with six broad stripes, and three narrower ones between each of the two broader ones, the centre one of the three the broadest—all running the whole length of the body, but are nearly lost before reaching the lower end: these stripes are again divided by transverse narrow ones. The tentacula are invariably twelve; the mouth is in the centre, and surrounded by brown flower-like markings. It does not attach itself, but lies buried in sand, with its head just above."

"The species readily assumes various shapes, as shown in the figures of it. It is quick in its motions, and buries itself in the sand when disturbed."

Cocks merely quotes an abbreviation from Peach's diagnosis, and adds:—"In pools with sandy bottoms, Gwyllyn-vase, Pennance, &c.; not uncommon." His figures are very unsatisfactory; in both only *eleven* tentacles are represented, although the text says "tentacula twelve"; in fig. 20 they are banded, but not so in fig. 21; in both the disc is quite plain. In fig. 20 the animal is

drawn in a vertical position, its base being expanded and attached to a stone; although it can stand upright in the water when in contact with a hard substance, it does so owing to the tenacity of the suckers of its physa, and not, so far as I am aware, in consequence of the latter forming a basal disc. Fig. 21 merely gives a foreshortened view of the disc and tentacles, and below it is an indistinct figure which is not referred to, and which apparently is intended to represent the aspect of the tentacles, &c., when buried in the sand. I mention this Paper and figures in detail to obviate the necessity of future reference, as the Annual Report in which it occurs is not easily accessible.

Gosse, in his Paper in the *Transactions of the Linnean Society*, 1855, adds no new facts; he speaks of its "sensitiveness to alarm, and the spring-like rapidity of its motions." He considered that there was a posterior aperture. Size, "very minute." In his *Marine Zoology*, 1855, and in his *Synopsis of the British Actiniæ*, 1858, Gosse merely alludes to the species; in the latter, he correctly constituted it the type of a new genus, to which he gave the name Halcampa.

In his *Monograph*, 1860, Gosse mentions that he had upwards of a dozen specimens sent him, in 1858, from Fowey. As these came from Peach's locality, their identity with the discover's species is beyond doubt, but the marking seems to be quite different from the original figure (*l. c.* pl. XXXVII., fig. 13). The latter, however, is very unsatisfactory. Gosse's description of the markings of the disc, also, does not particularly well agree with the woodcut he gives. The description is as follows:—

Column.—"Drab or dirty white; septa as white longitudinal lines; the swollen bladder-like extremity translucent.

Disk.—"Marked with a pretty star-like pattern, consisting of a pale-blue area inclosed in a pale line, and surrounded by twelve triangular rays of a dark-brown hue; each triangle surmounted by a pale, W-like figure, which incloses a dark-brown area, according to the accompanying pattern.

Tentacles.—"Pellucid brown, the front crossed by six semi-rings of opaque white, of which the second, the fourth, and the fifth (counting from the foot upward) are angular, the second pointing downward, the fourth and fifth upward. . . . The pellucid interspaces are tinged with brown, deepest on the first, second, and

fourth; and the first white ring surrounding the foot is sometimes tinged with sulphur-yellow."

The description of the specimens dredged by Sars, in twenty fathoms, at Ure, Lofoden Island, and also at Bergen, agrees so closely with some of the Malahide forms that there can be little doubt as to their identity. He describes the body as cylindrical, white; hyaline, with a brown epidermis; tentacles twelve, white; hyaline, with two brown rings; twelve brown spots round the mouth. The shape of tentacles and other points are identical in the two forms. The brown "epidermis" probably refers to the slimy sheath being beset with sand or other foreign particles.

The careful account of Meyer and Möbius leaves no doubt concerning the identity of their specimens with Peach's. They state that the body is smooth, flesh-coloured, with pale longitudinal lines; it generally covers itself with a tube of slime and sand grains. The tentacles are quite colourless, with two or three reddish-brown transverse bands, and similar longitudinal stripes at their bases; there are brown spots on the disc, each corresponding with the tentacle.

The authors refer to the extreme transparency of the dilated body, and to the presence of a pair of fine lines in the alternate broad red bands of the body, referring, of course, to the small secondary mesenteries (fig. 4, p. 12), and of which they give (pl. III., fig. C) a characteristic drawing. They found eight to eleven tentacles in their forms—length, 20–25 mm.; diameter, 2–3 mm. In mud, Bay of Kiel, 6–9 fathoms. They further identify with this species the two specimens found by Dr. Lütken, at Helleback in the Sound; but Andres (*l. c.*, p. 96), considers this a true Edwardsia, which he names *E. lütkeni.*

Dr. Andres correctly placed Sars' species in the genus Halcampa; but he believed that it was identical, save for characters "of the smallest importance," with *Halcampa farinacea*, Verrill, and, "rather than preserve a record of the two species," he unites them into one. Whether Verrill's species is identical with any European form is very doubtful, and the evidence would seem to point the other way: for the present, at all events, his name must stand.

The great range of variation of *H. chrysanthellum* suggests a critical examination of the two species which Keferstein described

from St. Vaast la Hogue (Manche, N. France), and for which he constituted the new genus Xanthiopus; his definition of this genus agrees so exactly with that of Halcampa, as defined by Gosse, that there is no doubt they are synonymous, and the latter has the precedence. The two species are yellowish in colour, and were found in the small chinks in the granitic rocks at extreme low water.

Halcampa (*Xanthiopus*) *bilateralis.*—The tentacles corresponding to the ends of the mouth are differently formed and without transverse bands, as in the other ten, and which bear two yellow transverse bands. All the tentacles are continued over the oral disc as triangular swellings to the opening of the mouth. About 40 mm. long.

H. (*X.*) *vittatus.*—All the twelve tentacles are similarly formed, with four yellow transverse bands; they do not run over the oral disc to the mouth. Mouth in the middle of a small, conical, raised, yellow ring. About 20 mm. long.

These two forms are undoubtedly the same species. Andres, also, is of the same opinion; but he, contrary to the British rules of Zoological nomenclature, re-names the species as *H. kefersteini*, consisting of "var. *α vittata*; tentacles equal; small size; and var. *β. bilateralis;* Gonidial tentacles different from others by lacking the annulations; larger size."

The pale colour and different appearance of the gonidial tentacles of the first species is not unfrequently met with in many of our British sea-anemones (e. g. *Tealia crassicornis*, Müll., *Actinoloba dianthus*, Ellis, and *Heliactis bellis*, Ell. and Sol.). The only other distinctions between the two species are different number of yellow bands on the tentacles, and the presence or absence of distinct radii on the oral disc—characters too slight to alone constitute specific distinctness. The conclusion at which we must arrive at is, that these two forms are merely varieties of *H. chrysanthellum.*

Dr. Ed. Grube found *H. chrysantellum* (*sic*) at Roscoff, buried in the sand at low water. He states that it only occurs in a single zone. "A few steps nearer the sea and one no longer finds it. These and the nearly allied Edwardsias are so completely hidden in the sand that their presence is not betrayed." He describes it as a perfectly white polyp, of the thickness of a swan's quill, with twelve short tentacles, and a single black point between each. The

lower portion of the body is described as being glandular, in the habit of forming a sheath for itself, having a revolving motion, and becoming swollen and transparent; he also noticed that its posterior end could adhere a little.

Landsborough, Milne Edwards, Hincks, Dana, Fischer, Andres, and Pennington, merely repeat previous descriptions more or less fully, but add nothing new thereto, so it is unnecessary to refer at length to them.

Previous observers have accurately described the general appearance and habits of this interesting little anemone. I need add only a few supplementary notes.[1]

In my former Paper I have figured what may be regarded as the general form of the animal when about half extended; but, as all observers have noted, the shape may be very varied. The physa is usually in a state of more or less distension; occasionally it assumes a very thin, rod-like appearance. (The physa is in this state when boring into the sand: compare the similar appearance of *Peachia hastata*, Gosse—Haddon and Dixon—*Proceedings of the Royal Dublin Society* (n. s.), vol. iv., pl. XVIII., fig. 7.) I have been unable to see a terminal posterior orifice, but there is a small perforation in each intermesenterial chamber close to its posterior ter-

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[1] My friend Mr. G. Y. Dixon has kindly allowed me to copy the following from his aquarium notes:—

"*November* 5, 1885.—Only one Halcampa survives [from September 26]. It, however, is in splendid health, and has grown considerably, being, when fully expanded, 2 inches long; scapus, $\frac{1}{4}$ of an inch in diameter; capitulum, $\frac{1}{5}$ inch. When fully distended it is quite transparent, and its œsophagus can be distinguished quite plainly running the whole length of the capitulum as a narrow, straight, pale-orange tube, which terminates just at the constriction which usually marks the limit between the scapus and capitulum. The twelve mesenteries are very conspicuous in the scapus, their inner free edges being orange, and shining through the pellucid body wall. With an inch objective you can distinctly see round glands (?) imbedded in the convoluted and swollen edges. The mesenteries are arched above where they run in to join the œsophagus, and are gradually sloped away as they come down towards the constriction which usually marks off the physa from the scapus. The clearness and transparency of the whole animal, but above all of the scapus, almost surpasses belief. I cannot find any marks on the physa like those in *Peachia hastata*." [This, of course, refers to rows of pores alluded to in our joint Paper.—A. C. H.]

"Four pairs of mesenteries are longer than the rest, and are more convoluted on their edges and more orange in colour; between each of these pairs is a mesentery which does not run down so near the physa; its edge is not so swollen or convoluted, and is more of a straw-colour than orange. Is it possible that this points to an affinity

mination. Similar pores, which by the way are very difficult to observe, were found in *Halcampa clavus*, Quoy and Gaim, by R. Hertwig, and I have also seen them in the so-called *Halcampa fultoni*, St. Wright. These perforations enable the physa to be suddenly emptied of its contained water. They exist in large numbers in *Peachia hastata*, both Mr. Dixon and myself being now satisfied that such is the true explanation of the appearances we described (*l. c.*, p. 403). The whole body is continually undergoing slow waves of alternate contraction and expansion. As Gosse states, the body is capable of great extension ("extend*i*ng to ten times its diameter or more). . . Specimens reach to an inch and three-quarters in length, and one-eighth of an inch in average diameter; the extremity is frequently inflated to one-fourth."

My longest specimen was about 50 mm. (2 inches) in length, and about 3·5 mm. ($\frac{5}{32}$ of an inch) in diameter at the middle. Other specimens measured about 31 mm., 38 mm., 44 mm., &c. ($1\frac{1}{4}$ in., $1\frac{1}{2}$ in., $1\frac{3}{4}$ in.) in length.

In nearly every case the tentacles, although monocyclic and perfectly uniform in size and shape, appeared to consist of two series. Those of the first series, which for the sake of convenience I term the primaries, are usually carried more or less arched forwards and inwards, and are also almost invariably more pro-

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with the octoradial Edwardsiæ?" [In connexion with the last paragraph I would quote the following from Dr. R. Hertwig's Report on the Actiniaria, Challenger Reports, *Zoology*, vi., 1885, p. 95.]:—

"The constitution of the septa in *Halcampa cavus* [Quoy et Gaim] shows further peculiarities worthy of notice, which seem to me to indicate its relation to the Edwardsiæ. As I was preparing a series of sections through one-half of the physa of the larger specimen, it struck me that three septa [mesenteries] (including the pair of directive septa [mesenteries]) were not so strong as the other septa, inasmuch as their longitudinal muscular cords became sooner indistinct (pl. xiii., fig. 7.) In the second smaller Halcampa, in which I was able to make sections through the entire body, four septa were somewhat smaller than the eight others; and, finally, Strethill Wright has described a parasitic Halcampa living on Medusæ (*Halcampa fultoni*), in which he can distinguish four stronger and eight weaker septa (*Ann. and Mag. Nat. Hist.*, ser. iii., vol. viii., p. 133, 1861). All this shows that an unequal development of the septa, and, consequently, a difference in their morphological value, is not unusual in Halcampa. If we assume that the eight stronger septa are homologous with the septa of Edwardsia, whilst the four other septa are new formations, then the genus Halcampa would present us with transition forms between the Edwardsiæ and the Hexactiniæ." [As the present communication is merely a critical note on the identity of the species in question, I do not intend on this occasion to follow up the line of thought here suggested.—A. C. H.]

minently marked and coloured. As they are prolongations of those mesenterial chambers which have no secondary mesenteries (see fig. 4, p. 12), and as one of them is situated at each end of the slit-like mouth, they therefore correspond to the primary tentacles of other Actiniæ. The tentacles of the second series (secondaries) usually bend outwards and downwards, being slightly recurved at the tip. Their colouration and pattern is often paler and more or less obscure.

The colour of the scapus is usually whitish, sometimes tinted with buff, and rarely opaque orange. As previously noted, when mature, the ovaries shine through the translucent body with a creamy orange colour.

The insertions of the mesenteries appear externally as longitudinal white lines: between each alternate pair of mesenteries there is a pair of small mesenteries, which appear on the outer surface as two thin white lines. This explains Peach's account of the stripes of the column, the "stripes" being the darker, *i.e.* translucent, areas between the mesenteries. The transverse stripes noticed by Peach are merely external corrugations due to the contractibility of the body. (See fig. 2, p. 12.) The capitulum is subject to considerable variation in ornamentation: usually it is buff, sometimes with a brown band. The white or pale-yellow bracket-marks alluded to in my former Paper appear to be very constant in their appearance.

It is, however, in the disc and tentacles that the greatest amount of variation occurs. I have therefore briefly described a number of variations to prove how careful one should be in laying any stress upon colour or markings, in dealing at all events with this species.

1. Disc opaque white. Tentacles very pale buff, with five paler bands; the lowermost two are waved or M-shaped. White bracket-marks externally at base of tentacles.

2. Disc pale lemon-yellow. Tentacles very pale buff, with five white bands, and some indistinct brown bands, which are much more distinct on the six primaries. A brown band round the capitulum, and pale bracket-marks.

3. Disc rusty colour, with distinct paler radiating lines (mesenteries), forming twelve dark-coloured wedges. Tentacles of same rusty colour, with five pale bands, the four upper of which are straight, and the lowermost is V-shaped. The inverted triangular

area left between this and the lowest straight line is dark in colour. A dark ring all round the base of the tentacles.

4. Disc pale, with a lenticular dark-brown mark in each radius, and external to it at the base of each tentacle a brown line. The six primary tentacles have the lowest half ring, dark in colour, and V-shaped, with a dark spot between the two limbs of the V; the other lines pale. The six secondary tentacles have pale indistinct markings, the lowermost of which is M-shaped. White external brackets.

5. Disc pale-buff round mouth, separated from the pale-yellow peripheral portion by a chain of dark-brown lenticular marks, which practically form a ring. At the base of each tentacle is a transverse dark-brown line; base of tentacle white; remainder pale-buff, the two colours being separated by a dark M-mark; there are also one or two indistinct pale-brown markings. At the base of each tentacle externally there is a lateral dark line, which slightly converges towards its fellow.

6. Disc pale, with alternate dark (primary radii) and light (secondary radii) lenticular marks. The primary tentacles are very dark; there is a basal M-mark, with a dark triangular mark a little way above. The external bracket-marks are prominent, and below each is a pair of dark spots.

7. Disc pale-orange, a white spot opposite each tentacle. Tentacles with five pale rings, the lowermost M-shaped. There is a small pale basal mark. The external bracket-marks are very plain.

8. Disc pale-buff; an indistinct pale V-mark in the centre of each radius. Tentacles with five pale rings, of which the lowermost is M-shaped.

One or two other varieties were seen, but a sufficiently careful note of the colour and pattern was not made.

The variations of the disc and tentacles are so many, that at first sight it seems almost hopeless to give any character which would be of service for specific determination. I have, however, ventured to give a drawing (fig. 3, p. 12) of what I take to be the general pattern of the disc and tentacles.

The following diagnosis will, I hope, be found to be essentially correct:—

Halcampa, Gosse.

Body elongated, cylindrical, divided into a capitulum, scapus, and physa; the mesenteries are more or less apparent throughout their whole length; except when fully extended, the body is corrugated; physa with minute suckers. Tentacles twelve, monocyclic, marginal, cylindro-conical. Disc plain; mouth linear, slightly prominent. British species—

H. chrysanthellum, Peach.

Form.—Body vermiform, extending to about ten times its diameter; smooth, or only secreting a mucous tube. Capitulum and tentacles completely retractile; physa large, non-retractile.

Colour.—Column whitish, occasionally slightly yellowish or buff, rarely orange; capitulum often more or less buff-coloured; a pair of pale bracket-marks ( ) usually present below the angles between the tentacles. The orange-coloured ovaries, when ripe, shine through the walls of the scapus, giving it a creamy-orange colour. The insertions of the mesenteries appear throughout the whole length of the body as white lines, and the suckers appear as white dots on the otherwise transparent physa.

Disc white, pale-yellow, or pale-buff; may be quite plain, or ornamented with variable brown markings.

Tentacles pale-buff, with five or six light or dark bars on their internal aspect, of which the basal is usually straight—the second M-shaped, the third V-shaped, the three (or four) upper being usually more or less straight. Externally, at the base, dark lines or spots are generally present.

Size.—30–50 mm. ($1\frac{1}{4}$ to 2 in.) long, when fully extended. About 3·5 mm. ($\frac{5}{32}$ in.) in diameter.

Habitat.—In sand or crevices of rock at low water, and down to 20 fathoms: S.W. England, E. Ireland, N. France, Norway, and Denmark.

This is the only recorded British species; but last summer I dredged a well-marked second species at a depth of forty fathoms off the mouth of Kenmare river, a description of which will in due time be laid before the Royal Irish Academy.

Halcampa fultoni, St. Wright (*Proc. Phys. Soc.*, Edinb., ii., p. 91, 1859), is, undoubtedly, an immature form. I obtained specimens of it which were parasitic on some Hydromedusæ

("Thaumantias"), in June, 1885, at Kingstown, county Dublin. I have observed several phases of its development, but could not obtain a sufficiently complete series to definitely state of what Actinian it is the larval form. My opinion, however, is, that it will prove to be the young of *H. chrysanthellum.*

The above communication is but a further contribution to the systematic knowledge of our British Actiniæ. I am fully aware of the morphological interest connected with the free Actiniæ, and though I have made some anatomical investigations on this form, I refrain from publishing them till I have examined a sufficient number of other sea-anemones to render a description and comparison profitable.

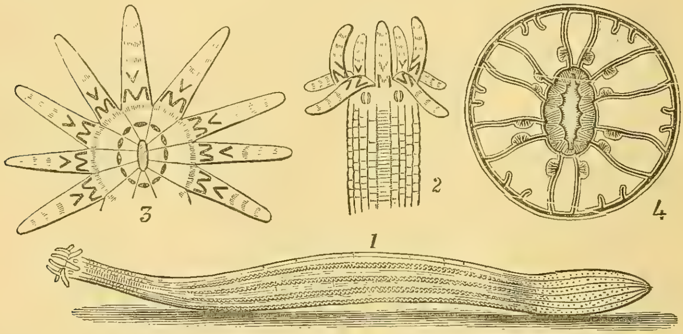


Fig. 1.—Side view of a fully extended *Halcampa chrysanthellum*, magnified about 2 diameters.

,, 2.—Generalized diagram of markings of oral disc and tentacles.

,, 3.—Side view of capitulum and tentacles.

,, 4.—Transverse section through the lower portion of the capitulum. The following points should be noted :—The arrangement of the muscular bands on the twelve mesenteries; the existence of a pair of very small secondary mesenteries in the alternate intermesenterial chambers; the existence of a pair of deep sagittal œsophageal grooves, which are provided with long cilia, and of five obscure furrows on each side of the ciliated œsophagus.

[Figs. 2, 3, and 4 are placed in the same relative position, and are not drawn to scale.]

II.—ON A NEW FORM OF CALORIMETER. By W. F. BARRETT, Professor of Physics in the Royal College of Science, Dublin.

[Read, June 15, 1885.]

An accurate mode of determining the specific heat of bodies, without the serious corrections that have to be introduced in the ordinary method of mixtures, is much needed. Mr. Joly has lately devised and described before the Royal Dublin Society a novel and ingenious method depending on the amount of steam condensed by the body; but I have not found this method answer so well for determining specific heats as for latent heats of vaporization; in the latter case it leaves little to be desired.[1]

The method devised by Professor Bunsen is well known. A convenient modification of Bunsen's calorimeter was made some time ago by Professor Emerson Reynolds, wherein the calorimeter takes the form of an alcohol thermometer with a large bulb, and having an arbitrary scale, the value of which is determined separately. The instrument I now beg to submit to the Society resembles the foregoing in so far as the cup for holding the body under experiment forms a portion of the thermometer, which, however is mercurial, and has a very open scale. The instrument is shown in the woodcut on next page, and its present form is mainly due to the valuable suggestions made, in the course of working with it, by Mr. J. M'Cowan, the Demonstrator of Physics in this College. As a piece of glass-blowing it is, I believe, unrivalled, and is a testimony to the skill of Mr. Hicks of Hatton Garden, London, who undertook to make it for me, and who informs me that the cup is blown out of a single piece of glass tubing.[2]

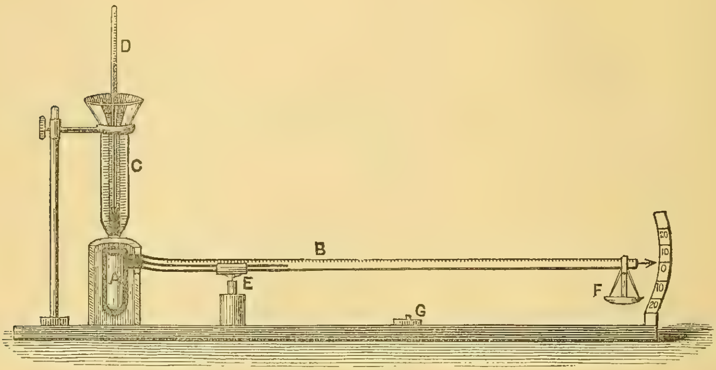
The cup, A, has a capacity of about 4 cubic centimetres; it is surrounded by a jacket of polished metal,[3] to prevent any slight loss

[1] I understand Mr. Joly has since improved his apparatus for finding specific heats.

[2] Since this Paper was read, Mr. Hicks has made several of these instruments, and can now produce them at a moderate cost.

[3] A simpler expedient is to silver the outside of the bulb of the thermometer by Liebig's process.

of heat by radiation, and is provided with a little silvered cover, G. The stem, B, is supported horizontally, and is graduated from – 5° to 70° or 80° Centigrade, and reads easily to tenths of a degree Centigrade. Supported immediately over the cup is a small burette, C, the level of the liquid in which can be very accurately read,



owing to the fact that only a longitudinal, narrow chink of clear glass is left in the centre, the sides being of opaque enamel. The mouth of the little burette is funnel-shaped, and its neck can be closed by the thermometer, D, it carries, the end of the thermometer bulb being ground to the neck or made water-tight by a small rubber ring. This thermometer is short, but has an open scale, and is graduated from about 30° to 100° C. Into the burette is placed the warm water or other liquid: by loosening the thermometer the liquid is allowed to run into the calorimeter, A, below; the mean temperature of the issuing liquid is thus accurately determined as it flows past the bulb. When the cup, A, is nearly full the burette is closed by pushing down the thermometer, D, and the cover, G, quickly placed over A: the highest reading on the stem, B is now taken. The volume of the liquid used is then read from the burette, and the operation is complete. But as the volume of the liquid has been measured, its weight must be found by taking its specific gravity for the temperature at which it was used.

To obviate this inconvenience, the weight of the liquid can be found directly in the arrangement shown in the figure.

Here the thermometer is turned into a balance, the stem being

supported by knife edges, E, somewhere near its centre of gravity. From the end of the stem a pan, F, depends, and beyond this a pointer, fixed to the stem, moves over a graduated arc. The pan is made of the right weight to exactly equipoise the arrangement at a given air temperature. The weighing of the liquid in the cup, A, is taken at this temperature; otherwise the varying length of the thread of mercury in the stem, B, would derange the balance. Except as a thermometer-stopped funnel for the liquid, the burette is, of course, not required in this arrangement.

In making a determination of the specific heat of a liquid with this instrument we require no cool liquid in A to mix with the warm liquid from C, for the bulb of the thermometer, A, itself forms both the containing vessel and the cool material to be warmed. All that is necessary is a careful determination, made once for all, of the heat capacity of the instrument. This constant factor, K, may in fact be found and stamped upon the base of each instrument before it leaves the maker's hands. As the constant is determined in precisely the same way that subsequent measurements are made, it includes, or rather it enables us to evade, all corrections, such as those due to the heat capacity of the vessel and of the thermometer, and also the loss of heat due to cooling if the same range of temperature be employed; and indeed, if otherwise, the silvered jacket and cover (which latter is necessary to prevent loss from evaporation) render the correction from this source negligible in ordinary work.

The constant, K, is found as follows:—

Let W be the weight of water used, T its original temperature (viz. that indicated by the thermometer-stopper); let t be the original temperature of the calorimeter (given on the stem, B), and θ its highest reading after the water has entered. As the heat lost on the one hand is equal to the heat gained on the other, and the specific heat of water is unity,

$$W(T-\theta) = K(\theta - t);$$

whence

$$K = W\frac{T-\theta}{\theta - t}.$$

When a determination of the specific heat, S, of a liquid has to be made, warm the liquid, and pour it into the burette; note as before

its temperature, T, as it issues, and afterwards find its weight, W'; note the rise of temperature of the calorimeter from t to θ; then

$$S = \frac{K}{W'} \frac{\theta - t}{T - \theta}.$$

A few minutes suffice to complete the whole determination to within a limit of error of one per cent. It will be obvious that for ascertaining the specific heat of small quantities of rare liquids this form of calorimeter will be found particularly applicable; and as the determination of the specific heats of organic liquids can thus be readily and accurately made, the instrument may be of use to chemists in the investigation of the molecular weights of such compounds.

The instrument is not quite so applicable for the specific heat of solids as of liquids; but it may be used for the former when they are in powder or in small fragments. In this case the calorimeter may first be heated by a known quantity of warm water, and the solid at the temperature of the air be dropped in; but this method does not yield good results, there being no turning point in the temperature. It is better to heat the solid in a small steam or water bath, and drop it into a known quantity of water contained in the cup of the calorimeter, the heat capacity of which is increased by this amount, so that its constant now becomes K_1. The solid may, of course, be weighed beforehand, so that the simpler unbalanced calorimeter can be employed.

III.—ON THE GASEOUS PRODUCTS OF THE KRAKATOA ERUPTION, AND THOSE OF GREAT ERUPTIONS IN GENERAL. By J. P. O'REILLY, C. E., President, Royal Geological Society of Ireland.

[Read, November 16th, 1885.]

The subject of the following Presidential Address is one sufficiently recent, and, owing to its magnitude, sufficiently important, to justify recurrence to it, notwithstanding the many points of view from which it has been already treated, and the fulness of the reports which have had for their object its description.

I do not propose to enter into a detailed examination of the different phases of this great event, so far as they have been recorded, but rather to call attention to certain aspects of the phenomena which, from the very first, seemed to me of the very highest importance, and as opening up a very wide and interesting field of inquiry. I allude to the gaseous agents and products of the great Eruption as manifested by the quantity and nature of the ejected matter, the intensity and range of the explosions, the resulting commotions of the atmosphere, and by the singular atmospheric phenomena which subsequently became visible all round the world, and even still manifest themselves daily.

In commencing, I will ask leave to refer to the article which, shortly after the arrival in Europe of the first accounts of the Krakatoa Eruption, appeared in *Nature*, September 13th, 1883, entitled "Scientific Aspects of the Java Catastrophe." With reference to this article, I wrote, on the 16th September, the following letter to that journal, which appeared in its issue of 27th September, and therefore, as will be seen, previous to the arrival of news relative to the wonderful appearances of the morning and evening skies:—

"Your excellent leading article on this great event omits to call attention to a factor which I have long maintained to be of

the greatest interest and importance from the points of view of meteorology and geology in general. I allude to the quantity of gaseous vapour emitted during the eruption. This must have a direct relation to the quantity of matter emitted (whatever its form), and also to the height and distance to which the matter may be ejected or carried. Now, I hold that such vast quantities of gases as must have been liberated on this occasion cannot be passed over, or taken as having no action on our atmosphere. Whatever the addition made, temperature and air currents are influenced by it, either locally, or over great extents of the earth's surface; and if it were possible to take account of the height attained by the gases, their temperature at liberation, and the point of the globe whence proceeding, some judgment might be attempted of their action. In the present state of meteorology we know nothing of these quantities, but it is justifiable to assume that the upper currents of the air may be thus profoundly influenced, and that in certain cases cyclones may thus be generated. The present very fine dry weather we are enjoying here, with the high and steady barometer, may be a result of the great eruption, and it will be worth while to note if any abnormal conditions of atmosphere be found to prevail during the coming months."

It was not until October 11th that an article appeared, noticing "a green sun in India;" therefore, quite subsequent to my letter. During the following months the wonderful "glows" which illumined the heavens, more particularly after sunset, interested men of science of every country, and they have been very generally attributed to the presence of vast quantities of dust in the upper regions of the atmosphere—this dust being generelly presumed to have resulted from the Krakatoa eruption. I may therefore, in some degree, claim to have anticipated the appearance of these sky glows, in so far as it is accepted that they are due to emissions from Krakatoa. I now propose to examine more extendedly the considerations upon which I based this anticipation.

It may not be out of place to remark, that in the study of natural phenomena we are easily led to attribute a relatively greater importance to agents which impress our senses than to those more occult in their action, and more particularly which do not leave distinct evidence of their influence. Thus, it is only quite recently that the *rôle* of dust in the formation of rain has

been demonstrated by Atkin, and the wondrous organic life of the ocean is essentially due to the presence of gases in relatively small quantity. Now, no class of agents in nature more easily escape attention or baffle investigation than gases, unless they present themselves physically or chemically fixed, so as to allow of their determination and measurement. The reason of this is obvious. Almost all the gases acting at the surface of the earth have densities less than that of air; consequently, unless restrained or brought into combination, they tend after emission to rise in the air, and becoming mixed with the atmosphere, pass to a very great extent beyond our observation and our control.

That the geologist should therefore attribute to them a rather subordinate and ill-defined part in the series of phenomena which he is called on to study can be understood. Brought, as he is, face to face with the rock masses forming the crust of the earth, or with the water masses which cover three-fourths of its surface, he naturally attaches importance to them, rather than to the gases which have ever acted, and are acting continually, from the interior or at the surface of that crust, but which by their very nature escape his attention even while still active agents, and which are so difficult of determination and measurement. There is, therefore, some justification for my calling attention, in this respect, to those earlier phases of the earth's development, which are usually treated as either purely of the domain of astronomy, or are not admitted as being tangible for the geologist.

Whatever the hypotheses which may be accepted as to the conditions of development of the earth, it is generally taken for granted that the successive phases of its existence have been similar in nature, if not in degree, to those which Science has been led to attribute to the other heavenly bodies. Thus we are led to believe that it has passed through all the phases observable in one or other of these heavenly bodies: from that of a nebula, becoming more and more condensed, to that of a sun; and from that of a sun through successive stages to the condition of things with which geology usually commences, that is, of a globe, having a crust or solid exterior, and therefore in a relatively cooled state, and capable of allowing the condensation of water on its surface and the existence of organic life thereon. Now spectroscopy and observation have shown that in the nebulæ, as in the comets and as in the

suns, gases play a very important part, if they be not the only constituents. For certain of these bodies it has been shown that carbon, and hydrogen, and hydrocarbons, are essential elements, both chemically and physically. Are we not, therefore, entitled to assume that these elements and combinations were abundantly present, and very active agents, in the first stages of the development of the earth, and if so, that traces of their influence may still be found both in our atmosphere and in the interior of the globe? Is it not reasonable to suppose that, in the slow and continuous process of contraction, very great masses of gases became retained or occulted by the cooling matter, and that these occulted gases have been the essential agents in balancing tensions in the continually contracting sphere?—that this continuous contraction led to the pressure of masses of these gases until heat was liberated in more or less degree, and frequently to the point which brought into play chemical affinities; and that thus the whole series of phenomena, which have tended and are tending to modify the form of the earth's surface, are intimately bound up with the existence and action of gases in the interior and at the surface thereof?

Thus, from the very earliest period, we are called upon to recognize the continuous presence of gases as essential constituents of the earth's mass, and, so far as analogy allows us to judge, as most active agents and products of alteration. For the period during which the crust was not yet formed they must have been predominating agents; while for the subsequent periods, during which the temperature decreased and the crust increased in thickness, their intensity of action must have gradually diminished, and their emissions become more and more spasmodic, or of longer period, until conditions were established which we now designate as volcanic, that is, when contraction could only take place by reason of the sinking of masses of the crust, with accompanying vulcanism and earthquake phenomena, such as we witness at the present time, one of the most important and constant of which is the emission of gases.

Leaving aside speculation as to the initial constitution, volume, and state of the atmosphere, and coming down to the period during which the earliest stratified rocks were being formed, we are led to imagine for that period a globe greater in diameter than at present,

having a crust relatively thinner and very differently constituted from what now exists; and, since we suppose an ocean of some depth and an erosive action, we are led to admit the formation of strata under conditions, in some sort, corresponding to those of the present state of things. Therefore we should represent to ourselves, at that period, an atmosphere having a direct relation, both as regards quantity and constitution, with the then phase of cooling and contraction of the earth. Moreover, we must suppose surface rocks, more or less altered, fissured, and penetrable, in which became retained chemically and physically a certain amount of gases which previously existed as atmosphere; and, finally, we have to picture to ourselves an ocean in which, as at present were retained in solution gases, also part of the then atmosphere, in quantity and quality relative to the temperature and constitution of the then ocean mass, and relatively to the prevailing atmospheric pressure. These conditions have continued to prevail up to the present time, but in degree and in proportions which must have depended, and must continue to depend, upon the successive phases of contraction and the surface changes of the earth. We can even imagine a last stage when contraction will tend to cease, when, therefore, the emission of gases will consequently become less frequent and more and more diminished, when the atmosphere as well as the ocean will become more and more chemically and physically retained by the rocks forming the crust, and when finally our earth will cease to have either an atmosphere or an ocean.

If I have thus ventured so far back into time, it is in order to distinctly establish the sequence of relation and the dependency which I conceive to have existed at all times between the cooling and contracting sphere and the atmosphere. And if we might comprehend under that term the sum of the gases existing—

(*a*) Free at the surface of the earth;

(*b*) In chemical combination with, and physically retained by, the rocks forming the crust; and

(*c*) The gases held in solution by the ocean and other waters;

then we might consider the sum $(a + b + c)$ as representing, or as being proportional to, the total amount of contraction effected since the period of the commencement of formation of the crust.

The "atmosphere," properly so called, would be that sum minus $(b + c)$.

Now one of the most interesting deductions arrived at from the examination of the fossil remains of the different geological formations is, that our atmosphere has certainly varied both in constitution and (most probably) in quantity, and if my assumption of an intimate relation of the atmosphere with contraction be correct, or admissible, there must have been periods or phases of marked contraction, and therefore of very active vulcanism and accompanying emission of gases, during or about these periods. Such geological data as we already possess certainly do point to periods of great volcanic activity, manifested by outbursts of lava and alterations of the earth's surface, and corresponding changes in the relations of land and ocean. The tertiary period may be cited as an example in this respect.

Turning now from what may, perhaps, be considered as mere speculation, to the phenomena of the Krakatoa eruption, it will be easily understood that, influenced by the considerations already developed, my attention was particularly drawn towards the *rôle* of the gases in this case, and that I was led to attribute to them an importance proportional to the magnitude of that event. Moreover, that very magnitude seemed to promise some phenomena of a nature capable of demonstrating that actual additions have thus been made to the atmosphere, and a due consideration of the details furnished of the event lead, in my opinion, very distinctly to that conclusion.

From the very careful reports made by their engineers to the Dutch Government, as well as from other sources, we have an estimate given us of the quantity of ashes emitted, which had fallen in such proximity to the locality, as to allow of an approximate measurement being attempted. Thus in the report which appeared in *Nature*, vol. xxx. p. 10, the author says: "I found that on calculating as accurately as possible the quantity of ejected solid substances, they reached 18 cubic kilometres as a safe estimate. These 18 kilometres represent a weight of more than (36×10^{12}) kg." He adds: "the volume of ejected gases was, perhaps, hundreds of times greater." Furthermore, he says: "However large the quantity may be, it does not nearly reach that which Tamburu produced in 1815, which Junghuhn estimated

at 317 cubic kilometres. This computation, however, rests on but few data, so that, in my opinion, a quantity of 150 to 200 cubic kilometres will come nearer the truth."

The quantity thus estimated for the Krakatoa eruption is evidently but a part of the total emission of solid matter: what proportion this heavier part of the ejected ash bears to the finely-comminuted matter, to the presence of which in the atmosphere the continuously recurring glows have been attributed, it would be impossible to say. How much more must be allowed for the still finer matter, which continues suspended at very great altitudes, which evidently encircles the earth, and to the presence of which is attributed the faintly coppery haze visible round the sun's image ever since the eruption, it is still less possible to estimate; but we can with safety say, that the quantity of vapour and gases emitted must have been in some degree proportional to the total quantity of ejected matter. We are further justified in assuming that the quantity of gas and vapour brought into action was not the minimum strictly necessary to project the totality of this solid matter into space; therefore any estimate of the quantities of these gases that may be attempted from the data accessible can only be much beneath the truth: indeed this is precisely one of those cases where, wanting any term of comparison, the mind is simply unable to exaggerate, even were there the will to do so.

Considering, therefore, only the portion of the ashes the volume of which has been estimated, and the data as to the height to which they attained, it is possible to arrive at a term of comparison for the quantity of gases emitted by comparing with the results produced by the use of gunpowder or other explosives.

In Berthelot's remarkable work, *Sur la force de la Poudre*, 1872, there is a table at p. 190, wherein for each explosive examined by him he gives the amount in volume of gases generated per kg. of consumed explosive matter, and the temperature in calorics attained. By the aid of this table an approximate value for the gases having acted explosively in the case of the Krakatoa eruption can be attempted. Let us consider in the first place the work done in the case of the discharge of a 100 ton gun, for which I find in *Nature*, vol. xxviii. p. 385, the

following data:—shell = 2000 lbs.; charge = 772 lbs. The extreme range of these guns is about 10 to 12 miles Eng. Now, as regards the height to which the ashes were shot up, we have the following statement (*Nature*, vol. xxx. p. 13):—"The steam cloud, according to the measurements taken on board the German man-of-war 'Elizabeth,' which left Anjar that morning at nine o'clock, must have reached a height of at least 11,000 m. During the much more violent explosion of Aug. 26th–27th the height, if the above report may be relied on, may very well have attained 15 to 20 km." (that is from 9·3 Eng. miles to 12·4 Eng. miles)—a height about equal to the extreme range of the 100 ton gun in question, and without taking into account the increased range which should be attained by a projectile shot vertically through air of continuously decreasing density.

Now, admitting that a comparison may be drawn between the action of gunpowder in such a cannon, and that of the gases or steam in the vent of a volcano, we have merely to take the estimate of the quantity of ashes thrown up during the Krakatoa eruption, and determine from that the corresponding charge estimated as gunpowder. According to the report in question, this quantity of ashes is given as 36×10^{12} kg.; and as the charge in the case of the 100 ton gun is to the projectile as $\frac{772}{2000}$, we may take as charge in the case of the emitted ash, $36 \times 10^{12} \times \frac{772}{2000} = 36 \times 10^{12} \times 0·386$, or approximately $36 \times 10^{12} \times 0·4 = 14·4 \times 10^{12}$ kg. powder. The table gives the amount of gases generated per kg. of powder as 0·225 mc. Therefore we have by the explosion of this supposed charge of powder $14·4 \times 10^{12} \times 0·225$ mc. $= 3·24 \times 10^{12}$ mc. at the pressure 0·76 mm. = 3,240,000,000,000 mc.

To appreciate what this cube means relative to our atmosphere, we may take this as having a height of about 5 miles, or in kilometres, about 8 km. high: dividing, therefore, this cube of gases by 8000 m., we have 405,000,000 kms. as the surface which would be occupied by a volume of air of that cube and 8 km. high: this would represent 405 kms., that is a surface of about 20 km. × 20 km. = 12·2 miles × 12·2 miles. But the height was really greater than 20 km., and has been variously estimated at 40 to 50 miles = 64·4 km. to 80·5 km. The quantity of ashes was much greater than that calculated, while

the author of the report in question considers "that the volume of the ejected gaseous substances was perhaps hundreds of times as large" as that of the ashes.

A similar calculation for the Tamburu eruption would give us a proportionally greater volume of gases, and in both cases merely terms of comparison, since, according to all the authors who have had occasion to describe eruptions witnessed by them, the quantities of gases and vapours emitted are great beyond all comprehension.

What, however, it is quite necessary to bear in mind, when considering this question is that, simultaneously with the Krakatoa eruption, gases and vapours were being emitted from a great number of vents over the earth's surface—some mere hot springs, from which the quantity of gas issuing, though continuous, is not taken account of; others, volcanoes of every degree of activity and violence, but only receiving attention when their violence is such as to compel observation, but in totality representing a volume of vapour and gas immensely greater than any estimate that can be attempted, since no term of comparison nor any measurement is at our disposal.

It may naturally be remarked that I include both gases and vapour, or steam, together, and that, according to the received ideas, the steam was essentially furnished by the sea-water which penetrated to the depths where the explosion originated. This is not, however, by any means proved. It is to be remembered that the amount of water held by the rocks, either chemically or physically, is estimated by Delesse to be much more than that of the ocean, and this water may sometimes be brought into action. But even admitting that all the water ejected as steam came originally from the sea, the sudden transformation of such a quantity of water into steam, and the sudden projection of such quantities of it into the air, must have influenced both the sea currents and the atmospheric currents, and in this way merit being taken into consideration. But in eruptions, along with the steam, or independently of it, gases are most certainly projected into the air. That such were notably present in the Krakatoa eruption is certainly stated by an eye-witness, a captain of one of the vessels which happened to be in the neighbourhood, who says "the presence of a powerful marsh gas was also easily

detected."—*Nature*, vol. xxix. p. 29. Moreover, from the observations of Fouqué at Santorin, and of St. Claire Deville at Vesuvius, we know that hydrogen occurs as one of the emitted gases. The following is a Table given by Fouqué, p. 227 of his work on Santorin, of the gases collected on the 17th March, 1877, at that place :—

	I.				II.		
SH .	Trace	..	..	..	..	..	0
CO^2 .	37·04	37·24	36·42	36·60	0·07	1·49	78·44
C^2H^4 .	0·43	0·47	0·86	0·81	0·71	0·42	0·64
O . .	0·41	0·51	0·32	1·46	21·56	18·45	3·37
N . .	35·02	33·66	32·97	32·04	76·04	79·64	87·55
H . .	27·10	28·12	29·43	30·09	1·62	0·00	0·00

I.—Taken in fissures. II.—Taken at the surface of the sea.

It must further be remembered, that very frequently, previous to eruptions of active volcanoes, gases are emitted from the craters and cracks of the volcanoes, and that the emission continues long after the cessation of eruptive activity, and may continue for centuries when the volcano passes into the state of a hot spring. Finally, all over the world, both on land and in the ocean, as has been already remarked, this emission is going on continuously from the active volcanoes, the hot springs, and simple jets of gas, and the daily total of this quantity of gas must be something past all calculation.

It may be objected that were there such continuous additions being made to our atmosphere, Science would already have ascertained the fact by comparative barometric observations. But it must be remembered that such barometric observations should embrace the whole earth's surface, and have been recorded for a sufficiently long time to allow of any effective comparison—that the observa-

tions made at sea must be limited to a relatively small number of points or zones—that the polar regions must be perhaps for ever closed to observation. Again, the constitution of the upper parts of the atmosphere, above 7 miles = 11,000 m. height, are quite unknown to us, and will probably ever remain so, since no living being can exist at that height. Lastly, that account must be taken of the porosity of the surface rocks and soil, and of the ocean, which can absorb and retain quantities of gases, variable relatively to temperature and pressure. Thus supposing the volume of the atmosphere to be actually doubled by volcanic emission at a given moment, it does not at all follow that the barometer would show that increase of volume in totality and at once, since the pressure on the surface of the earth would cause a certain portion to be taken up by the soil and rocks, and a certain other part by the water. In this respect, indeed, we should perhaps look to the ocean as a far more reliable witness to variations of volume in our atmosphere ; and were the analyses of ocean water sufficiently numerous, both as regards local distribution and depths, and extended over a sufficiently long period of time, they would manifest by changes in the quantities of contained gases much more accurately, and with much more chances of sound comparison, variations in the volume of the atmosphere, than would barometric measurement. Here there is room to remark that the quantity of gases contained in the ocean and other waters must be in intimate relation with their organic life, and that, consequently, the greater or lesser abundance of fossils in certain formations must bear some relation to the quantity and nature of the gases contained in the sea in which they were deposited, and these gases were in relation to the volume and constitution of the then atmosphere. Thus we have probably, in the fossils of the different formations, real measures of the atmospheres, corresponding to the periods of their deposition.

Were it possible to determine directly the gases given forth from any one of the existing active volcanoes, no more valuable scientific work could be attempted, but the difficulties are evidently immense, if not insurmountable, unless in the case of some small volcanic cones, where it might be possible to make such an attempt. But these difficulties only enhance the value of all measurements and determinations of the emissions of gaseous hot springs and

cold springs, which may be considered as bearing some relation to the total volcanic activity.

The oil-springs of America and of the Caspian must be considered as coming into this category, since, by their constitution, they are akin to certain of the gases which accompany volcanic action, and nothing yet absolutely proves their organic action.

With this continuous emission of gases and steam must in some way be connected the slow movements of the earth's surface, which are now being more attentively studied than had been the case; and did we posses sufficient data in respect of these emissions *in toto*, it might be possible to foresee the recurrence of volcanic eruptions, or of earthquakes, and of disturbances of the earth's surface. Still more important is the bearing of this total emission of gases and vapour on the question of the radiation of earth heat into space. As the points from which the gases come are certainly situated at relatively great depths, and in the case of such eruptions as that of Krakatoa most certainly at a very great depth, the surface radiations must be considered as forming part of a total radiation, some terms of which correspond to points deep in the interior of the earth. That the seat of the great explosion of Krakatoa was very deep may be inferred from at least two facts—the one, that the "recoil" (to use the expression) of the explosion was felt at or near the antipod of that point, as observed by Monsieur Forel in *Nature*, March 26, 1885. He states that underground noises were heard at Caiman-Brac, in the Caribbean Sea, in August, 1883, contemporaneously with the eruption, the exact antipod of Krakatoa being the middle of the State of Colombia, on the Magdalena river, between the towns of Antigua and Tunja.

Another fact which would lead one to infer that the seat of the explosion lay very deep was, that the island was split according to an east-to-west direction, so that the whole northern part became detached, and sank to a depth of 200 m., or more. "In the place where the fallen part of Krakatoa once stood there is now everywhere deep sea, generally 200 m.—in some places even more than 300 m. deep" (*Nature*, vol. xxx. p. 12). Now this splitting in an east-to-west direction may perhaps be considered as the result of the lateral pressure and intense friction of the solid matter, when being ejected, against the west side of the vent, since coming from a

great depth, and having only the initial angular velocity corresponding to that depth, it should lag more and more as it rose to the surface of emission. This lateral pressure and friction would, to a certain extent, explain the comminution of the lava, and the formation of the very fine dust.

That Krakatoa, and indeed the whole of Java, having for antipod the north-western coast of South America, must in like manner, to some extent, feel the "recoil" of eruptions and earthquake shocks happening in the latter localities, may be expected, since we have here the occurrence of the exceptional case of land having for antipod land, and as can be seen at a glance of the map exhibited, showing the antipodes of the countries of the Eastern Hemisphere, South America, and part of Asia correspond in a very remarkable manner, while at the same time they represent the most active seats of volcanic and earthquake action. Were the soundings of the ocean and our bathymetrical maps complete in this respect, and could these soundings be verified periodically, it would perhaps be found that, corresponding to the volcanic and earthquake actions which take place in one hemisphere, movements of the bottom of the ocean take place in the opposite hemisphere, and that thus the deformations resulting from a continual contraction are being balanced, so as to maintain the uniformity of the earth's movement.

There is one last point relative to the great eruption to which I venture to call attention; it is that of the periodicity of such great outbursts.

One of the remarks made relative to Krakatoa in the article of *Nature* already referred to, vol. xxx. p. 10, is, that the volcanoes of the Straits of Sunda had been in a state of quietude during 200 years, and that during the latter years a great many earthquakes took place along the fissure on which they are situated. Now, in the same vol., p. 435, is a very interesting article on the frequency of earthquakes in Japan. It is stated that the Japanese have attempted to prove that earthquakes run in well-defined cycles, a by no means novel or very modern idea. Wernich, in his *Geographische Medicinische Studien*, says "that severe earthquakes occur in Japan every 20 years." The Japanese journals, working on records relative to the period included between the dates

A.D. 628 and A.D. 886, have divided it into 26 periods of 10 years, between which the following intervals occur :—

40	years	between the	2nd	and	6th,
60	,,	,,	6th	,,	12th,
40	,,	,,	12th	,,	16th,
40	,,	,,	16th	,,	20th,
40	,,	,,	20th	,,	23rd;

and from "the author's explanatory notes a still more correct table can be deduced, by means of which the cycle of earthquake intensity is finally put at 33·3 years, or 3 × 11·1, that about three times the sun-spot cycle (Lockyer gives 10 years; Flammarion $11\frac{1}{9}$).

A further deduction is made, that earthquakes of a disastrous nature occur once every 59 years, so that the next great catastrophe may be expected in 1913.

Now it will be remarked that the interval of 200 years of rest mentioned for Krakatoa so far corresponds to a multiple of the short period of 10 years, adopted as interval of groups, representing also the period of sun-spots.

Admitting that the earth were once in a state somewhat as is now the sun, may it not have had in a similar manner a recurrence of phenomena such as the sun-spots, and may not this recurrence be still observable in the existence of a period or cycle in volcanic and earthquake action? When working at the Catalogue of European earthquakes which I submitted to the Royal Irish Academy last April, I noted a recurrence of a period or interval of 10 years in many cases, but so exceptionally that I could not point to it as a law; however, a further examination of the data existing may be more conclusive in this respect.

IV.—ON A NEW SPECIES OF *OROPHOCRINUS* (PENTREMITES), IN CARBONIFEROUS LIMESTONE, COUNTY DUBLIN. ALSO REMARKS UPON *CODASTER TRILOBATUS* (M'COY), FROM CARBONIFEROUS LIMESTONE, COUNTY KILKENNY. By WILLIAM HELLIER BAILY, F.L.S., Etc. (Plate I.)

[Read, February 16, 1885.]

Orophocrinus (Pentremites) prælongus (n. s.):

This Blastoid is remarkable for its size and elongated character, compared with others of the genus.

Its general outline is that of a lanceolate body (*calyx*), with a pentagonal summit, its greatest diameter being at the termination of the ambulacra eight-tenths of an inch from the summit, decreasing regularly towards the base and terminating obtusely, without any trace of stem.

The basal plates, conical in shape, extend upwards to about one-third of its length, measuring nine-tenths by seven-tenths of an inch; the radial plates are oblong, one inch and a-half by three-quarters of an inch at the widest part; the deltoid plates are small and triangular, extending only to about three-tenths of an inch from the summit, the five plates forming a pentagon when viewed from above.

The ambulacra are narrower than in *O. inflatus;* the small plates composing each are arranged in two alternating series, with a deep groove down the centre, and are inclined towards each other at an angle of about 15°; there are sixteen of these plates in the space of a quarter of an inch.

The mouth, which was small and central, and ovarian apertures are not sufficiently well shown for description.

Length, two inches and five-tenths; breadth at widest part, one inch and six-tenths.

Plate I., figs. 1, 1A, 2, 2A, 2B.

Localities.—St. Doolagh's and Raheny, Co. Dublin, in lower carboniferous limestone; collection, Geological Survey of Ireland.

CODASTER TRILOBATUS AND ACUTUS, M'COY:

Of this genus (belonging to the same class of Echinodermata, the Blastoidea), established by M'Coy under the above name,[1] he describes two species which appear to be identical.

Some years ago I was fortunate enough to collect several well-preserved specimens of this fossil, which I refer to *C. trilobatus*, as indicative of the most usual form, resembling very much that of a hazel nut, although there are gradations between both that and the variety M'Coy has figured under the name of *C. acutus*.

As I believe it has never yet been recorded from Ireland, I now bring it before the notice of this Society.

Our specimens were obtained from shales between the carboniferous limestone at an old quarry at Lisdowney, near Ballyragget, county Kilkenny; collection, Geological Survey of Ireland.

Its locality in England is stated in the *Synopsis* to be Bolland, Derbyshire.

Plate I., figs. 3, 4, 4A, 4B, 5, 5A.

NOTE ADDED IN THE PRESS.

Since this Paper was read, Messrs. P. Herbert Carpenter and Robert Etheridge, Junior, who are studying the subject, requested a loan of the specimens, which, at their request, were submitted to them for their examination. Although agreeing with me that figs. 1, 1A represent a new species (*Pentremites prælongus*), they consider the form represented on figs. 2 and 2A as a different species (*Orophocrinus pentangularis*, Müller sp.).

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[1] Synopsis of British Palæozoic Fossils, 1885, pp. 122, 123, pl. 3D, figs. 7, 8; *Ann. and Mag. Nat. Hist.*, 2nd series, 1849, vol. iii. 251.

EXPLANATION OF PLATE I.

Fig. 1.—*Orophocrinus* (*Pentremites*) *prælongus*, Baily. Lateral view, natural size, from carboniferous limestone, St. Doolagh's, Dublin.

,, 1A.—Do. do. Section of ditto.

,, 2. —Do. do. Natural size, carboniferous limestone, Raheny, Dublin.

,, 2A.—Do. do. Natural size, view of the summit.

,, 2B.—Do. do. Portion of ambulacral area enlarged three diameters.

,, 3. —*Codaster trilobatus*, M'Coy. Lateral view, natural size.

,, 4. —Do. do. var. *acutus*, M'Coy. Lateral view, natural size.

,, 4A.—Do. do. do. Ventral surface of same, showing pentagonal mouth and ovate anal aperture, natural size.

,, 4B.—Do. do. do. One of the ambulacral areas of same, showing perforated plates, and intermediate *jointed* ridges, enlarged four diameters.

,, 5. —Do. do. do. Small ovate specimen, natural size.

,, 5A.—Do. do. do. Basal view of same, natural size, showing convex central disk perforated for attachment of stem.

Figs. 3, 4, and 5 from specimens obtained in shales of lower carboniferous limestone, Lisdowney, near Ballyragget, county Kilkenny.

V.—A TABLE OF THE IRISH LOWER PALÆOZOIC ROCKS, WITH THEIR PROBABLE ENGLISH EQUIVALENTS. By G. HENRY KINAHAN, M.R.I.A., ETC.

[Read, May 18, 1885].

Silurians (*including* Devonians *or* Lower Old Red Sandstone).

Localities.	Irish Groups.	English Equivalents.	Remarks.
Cork, ...	Glengariff grits, ...	Lower Old Red Sandstone and Lower Devonian.	A zone of Eurites in the Glengariff grits. The Glengariff grits graduate upwards into the Old Red Sandstone (*Jukes*), *i.e.* the passage-beds between the Silurians and the Carboniferous. The representatives of these "passage-beds" are probably only found in the following Irish localities:—S. W. Cork, Central Kerry, Slieve Mish series; and in the county Mayo, about Clew Bay, at Louisburgh, Clare Island, and Mulranny. Elsewhere the rocks of the red arenaceous type, classed as "Lower Old Red Sandstone," probably are the equivalents of the Dingle beds, and are a part of upper beds of the Silurians.
Kerry, ...	Dingle beds, ...	Lower Old Red Sandstone and Lower Devonian.	Jukes also included the Anascaul beds in the Silurians, but it appears as if they more probably belong to the Ordovicians (Cambro-Silurians).
,,	Croaghmartin beds, ...	Ludlow (?), *Salter*.	
,,	Ferriter Cove beds, ...	Wenlock (?), *Salter*.	
,,	Smerwick beds, ...	Mayhill Sandstones. . . .	The Smerwick beds are probably, at least in part, the "passage-beds" between the Ordovicians (Cambro-Silurians) and the Silurians, or, perhaps, the equivalents of the Lower Devonian.

North-west Galway,	beds,		
,, ,,	Creggaunbaun group, . . .	Wenlock and Upper Llandovery.	—
,, ,,	Mwelrea and Toormakeady groups,	Lower Old Red Sandstone and Lower Devonian.	A zone at or near the base of these groups is remarkable for having associated with it rocks containing fossils of Caradoc types.
,, ,,	Salrock slates, ...	Ludlow (?).	The most numerous fossil is said by Davidson to be of an Upper Llandovery type.
,, ,,	Lough Muck series with the Eurite series,	Upper Llandovery fossils.	In the Lough Muck series there is a zone in which the fossils are of Caradoc types.
,, ,,	Gowlaun, Kilbride, and Cong series,	Upper Llandovery and Wenlock.	To the westward, at Gowlaun and the Blackwater, the fossils are principally of Llandovery types; while eastward, but on the same geological horizon, at Kilbride, Benlevy, and Cong, they are principally of Wenlock types, with some of Ludlow types.
North-east Connaught and South Ulster,	Ballaghaderreen series, . . .	Lower Old Red Sandstone, Lower Devonian, Upper Llandovery, and Wenlock.	Below and above, the rocks, lithologically, are Lower Old Red Sandstones, but coming in between them as a lenticular mass are rocks containing fossils principally of Llandovery and Wenlock type; a few of them, however, are of Caradoc types. In them is a zone of Eurites similar to the rocks of Cork, Kerry, Galway, and Mayo.
,, ,,	Curlew Mountain beds, . . .	Lower Old Red Sandstone or Lower Devonian.	These also contain a zone of Eurites.
,, ,,	Drumshambo beds, ...	,, ,, ,,	—
,, ,,	Fintona Mountain beds, . .	Lower Old Red Sandstone or Lower Devonian and Llandovery (?)	One, or perhaps two zones of Eurites; some of the limestones are probably fossiliferous.
Londonderry, . . .	Draperstown district,	Lower Old Red Sandstone or Lower Devonian.	An outlying patch to the north of the Fintona Mountains area. Only the basal beds exposed.
Antrim, ...	Cushendun Conglomerate,	,, ,, ,,	—

ORDOVICIAN *or* CAMBRO-SILURIAN.

LOCALITIES.	IRISH GROUPS.	ENGLISH EQUIVALENTS.	REMARKS.
Leinster and Munster, .	Upper or Slieve Phelim series,	Lower Llandovery and Caradoc.	The fossils are principally of Caradoc types; but at Ballycar, county Clare, there is in them a colony of Upper Llandovery types.
,, ,,	Middle or Ballymoney series,	Caradoc-Bala.	These may be subdivided into the *Upper Red and Green Slate* or *Slievebwe group*, the *Middle* or *Eruptive-rocks group*, and the *Lower Red and Green Slates* or the *Courtown group*. The fossils nearly solely are confined to the middle group, and are of Caradoc-Bala types; but in some subordinate black shales there are fossils of Llandeiloe types.
,, ,,	Lower or Dark Shale series, .	Llandeiloe.	The fossils are principally of Llandeiloe types; a few, however, are of Caradoc-Bala types.
Kerry, ...	Anascaul beds, ...	Caradoc-Bala.	The general assembly of fossils appear to be of Caradoc-Bala type, although some are said to be of Upper Llandovery types.
Galway and Mayo, . .	Lettermullen and Croaghpatrick series,	Caradoc-Bala and Llandeiloe.	All these rocks are more or less altered, but they appear to be the equivalents of the rocks of the middle and lower series in Leinster and Munster.
Mayo, ...	Doolough series, ...	Llandeiloe.	—

		or in part Mayhill sandstone.	more of a Caradoc type, but W. Swanston has considered them to be more of Lower Llandovery types.
Fermanagh, ...	Lisbellaw series, ...	Caradoc.	These appear to be on a slightly lower horizon than the rocks of the Pomeroy series.
North Tyrone, Londonderry, and Donegal,	. . . .	Caradoc-Bala and Llandeiloe. Perhaps in part Mayhill sandstone or Lower Llandovery.	These rocks are all more or less metamorphosed; some of them appear to be on the same geological horizon as those of the middle and lower series of Leinster and Munster. But others, as in the south of the county Donegal, are probably on the same horizon as the rocks of the upper series.

CAMBRIANS, *including the* ARENIG GROUP (PASSAGE-BEDS).

LOCALITIES.	IRISH GROUPS.	ENGLISH EQUIVALENTS.	REMARKS.
Galway, Mayo, Sligo, and Leitrim,	Great Micalyte and the Lettermore series, Connemara lower series, . .	Arenig group. . . . . . Cambrians (Upper ?).	The Connemara lower series include the groups Nos. 1 to 8 of the section given in the Geological Survey Memoir. In Connemara the great thickness of strata below the known equivalents of the Llandeiloe beds (Doolough series) must be the equivalent of the Arenig group and a portion of the underlying Cambrians; they, however, are all more or less metamorphosed. Other more or less similar rocks which occur in the Ox Mountain range, between Westport in Mayo, and Manorhamilton in Leitrim, are probable, also, the equivalents of the Arenigs and the underlying Cambrians.
North-west Mayo, . .	Erris Head series, ...	Cambrians (?).	These rocks are much more altered than the associated rocks, and were considered to be older than them by Griffith and more recent observers; yet no unconformability has been proved or seems to exist between the two. If they are older than the associated rocks, which are evidently the equivalents of a portion of the Ordovicians, they probably are equivalents of a portion of the Cambrians; but it is very improbable that they are equivalents of the Laurentians, as has been suggested.
North-east Mayo, . .	Lurga (Ballaghaderreen) series,	Arenig group (?)	These rocks appear as an isolated detached outlying exposure, and their age is quite conjectural. Possibly they may be the equivalents of the Arenig group; but it is quite as possible that they may be the equivalents of the middle or

			Galway, which are considered to be the representatives of the Arenig group, while they are much older than the associated rocks of the Pomeroy series (*Ordovicians*).
Donegal, ...	Boylagh and Kilmacrenan, .	Arenig group (?)	In the north-west of the county Donegal are rocks that have been suggested by Jukes to be possibly of Laurentian age; this, however, seems to be improbable. Possibly some of them may be the representatives of the Arenig groups, or even of some of the underlying Cambrians. In them obscure markings like some of the Ordovician fossils were found by Dr. W. King of Galway; but as yet their claim to be considered such has not been satisfactorily proved.
Down, ...	Craigowen, ...	Cambrian (?)	These rocks in aspect are like the Bray Head, county Wicklow, Cambrians, on which account DuNoyer suggested that such might possibly be their age. No fossils as yet have been found in them.
Longford, ...	Granard beds, ...	Cambrian (?)	On account of their likeness to the Bray Head rocks, Foot suggested that they might be Cambrians. They seem to be separated from the associated Ordovicians by either a fault or an unconformability.
Dublin, Wicklow, and Wexford,	Howth, Bray Head, Carrick, Cahore, Carnsore, and Bannow groups,	Lower Cambrians. . . .	*Oldhamia antiqua*, *O. radiata*, and *O. discreta* are characteristic of these rocks. In the Howth group *O. antiqua* only has been found; in Bray Head both *O. antiqua* and *radiata* are locally abundant; in the Carrick group the form is generally *O. discreta*; in the Cahore district the more abundant is *O. radiata*, although in other places there are a few bits of *O. antiqua*, while in the Bannow district the fossils found seemed more allied to *O. discreta* than the others.

VI.—ON THE OCCURRENCE OF AN OUTLYING MASS OF SUPPOSED LOWER OLD RED SANDSTONE AND CONGLOMERATE IN THE PROMONTORY OF FANAD, COUNTY DONEGAL. By EDWARD HULL, LL.D., F.R.S., Director of the Geological Survey of Ireland.

[Read, December 16, 1885.]

The district where this mass occurs lies between Lough Swilly and Mulroy Bay, and is formed chiefly of metamorphic beds of quartzite, schist, trap, and crystalline limestone. The tract of Lower Old Red Sandstone lies along the northern base of the Glenalla Hills, rising into a high ridge of quartzite, &c., which strikes across the promontory in a N.E. and S.W. direction, and attains to an elevation of 1,196 feet. The beds of sandstone and conglomerate are let down by a large fault against the older rocks, and form a low, rocky tract, lying for about two miles along the northern base of the mountain, and were recognized by the officers of the Geological Survey when engaged in that district during the summer of this year. They consist of alternating beds of reddish soft sandstone, generally pebbly, and often forming massive conglomerates, with large blocks of quartzite, schist, limestone, and trap.

The dip of the beds is S.S.E., or towards the base of the quartzite ridge; and, measured across the strike, the mass is one-quarter of a mile across, and the estimated thickness is about 800 feet. Red shales, and flaggy sandstones also occur, and are seen resting unconformably on the quartzite beds of the metamorphic series.

From the general resemblance of these beds to those referable to the age of the Lower Old Red Sandstone in the district of Omagh and Dromore to the south, as also on the coast of Antrim and Scotland in an easterly direction, I am disposed to refer them to this formation, rather than to one of a more recent period, such as the Carboniferous; but in the absence of fossils and the entirely isolated position of the beds, the question of their geological age must remain somewhat indeterminate. They seem to have been formed within the limits of a basin separated from any of the other basins of Lower Old Red Sandstone either in Ireland or Scotland, and will prove a new feature in the Geological Map of Ireland.

VII.—ON A METHOD OF DETERMINING THE SPECIFIC GRAVITY OF SMALL QUANTITIES OF DENSE OR POROUS BODIES.

By J. JOLY, B.E., Assistant to the Professor of Civil Engineering, Trinity College, Dublin.

[Read, January 20, 1886.]

A METHOD of determining the specific gravity of a small quantity of a heavy mineral is often a *desideratum* in the course of inquiries into the composition of rocks, sands, volcanic ash, &c. The mineralogist is indeed frequently called upon to determine the nature of minerals distributed but sparsely throughout his specimen, or even when abundant—from the intimateness of their intermixture with other substances—only procurable in very small fragments, and, except with the expenditure of much time and labour, in very small quantities. The same case arises when it is not desirable to deface an implanted specimen of rare beauty of form. Finally, the chemist is often called upon to determine the physical properties of minute quantities of matter, as in the case of the rare elements.

Whether as a characteristic for discrimination, or as a physical property to be placed on record, the quality of specific gravity is of sufficient importance to justify me in calling your attention to a method of determining it, specially applicable for dealing with small quantities of very dense bodies, and also with small quantities of porous, fibrous, or very cleavable bodies.

The method now in general use for the micro-determination of the specific gravities of silicates, &c., of low density is by balancing in a liquid of a specific gravity, adjustable to that of the specimen, and subsequently determining the density of the solution employed.

This method fails altogether—

(*a*) When the substance has a specific gravity—over four.
(*b*) When the substance is of a porous nature.

In the first case the method fails, for want of a liquid of sufficient density to equilibrate the solid. Indeed we cannot

readily extend the method above the specific gravity 2·77, that of Thoulet's solution (the mutually-saturated solutions of biniodide of mercury and iodide of potassium). The solutions necessary to extend the range above this are either costly or difficult to work with: some can only be used by maintaining them at a high temperature (as lead chloride at 400° C.). In any case the range of density hardly passes that of garnet, 3·4 – 4·3, and I am not aware of any other published method of dealing with small fragments of minerals of a specific gravity exceeding this. In short, if a few milligrams of any of the host of minerals ranging above 4·5 in density—about 90 per cent. of the unsilicated mineral species—be presented to the mineralogist, he is *unable* to determine this characteristic.

In the second case—the case of porous bodies—the impossibility of freeing the body from contained air, when immersed in liquids of the nature of those to which we are restricted, renders the method fallacious. The air-pump or the application of heat will generally be found of little avail. In this case we must again seek a large quantity of the substance, so that we may be able to weigh it in a liquid of low-surface tension, or of a 'creeping' nature, such as turpentine or alcohol. Small quantities cannot be dealt with.

The method to be now described enables the specific gravity of substances to be determined under both these conditions—that is, whatever their density or whatever their state of aggregation—in extremely minute quantities, with an accuracy limited only by the sensitiveness of the chemical balance, and by the aid of solutions of a density varying from about that of water to say twice that of water: but this is under our own control. Unfortunately, it is inapplicable to the purpose of effecting the separation of bodies of different specific gravities.

Briefly, the theory of the method is as follows:—The mineral by itself will not float in any known solution, suppose. If, however, we mix it with another substance of much lower specific gravity, there is easily found such a proportion for the constituents as will enable the mixed bodies to be equilibrated by dilution of the specific gravity liquid. We may, in short, adjust the specific gravity of the mixed substances to be as close to that of either of them as we please.

We require to know—

W	the weight of the mineral,			
ω	,,	,,	,,	buoyant substance,
σ	,,	sp. gr.	,,	buoyant substance,
s	,,	,,	,,	mixed substances,

in order to determine S, the specific gravity required.

Then, as

$$\text{sp. gr.} = \frac{\text{weight}}{\text{volume}},$$

$$S = \frac{W}{\frac{W+\omega}{s} - \frac{\omega}{s}},$$

$$\text{or} \quad S = \frac{W\sigma s}{(W+\omega)\sigma - \omega s}.$$

By this means, then, we can evidently deal theoretically with bodies of any specific gravity; and, further, if for the buoyant substance we chose one which, when brought to a liquid state, will creep into and surround the substance, we may evidently be independent of conditions of aggregation, and all trouble with contained air, or bubbles adhering to the surface of a rough fragment, avoided.

How the method is practically carried out I now proceed to describe.

The specific gravity of a piece of translucent, homogeneous paraffin, free from bubbles, is taken by any of the ordinary methods—weighing in water with a sinker, or balancing in a mixture of alcohol and water, and then determining the density of the solution. The value found is what I called σ above, the specific gravity of the buoyant substance. There is no better paraffin for our purpose than that sold in the form of candles; nor do I see any reason to seek any other substance. It fulfils all requirements, its penetrativeness when melted and its translucency when solid leave nothing to be desired.

From this piece of paraffin a little disk-shaped piece—about 3 or 4 mms. in diameter, and 1·5 mm. thick—is cut with a sharp knife, cleanly paired and smoothed on the edges by gently rubbing between the fingers. The disk is larger or smaller according to the quantity of mineral at our disposal, and if great accuracy be desired we determine its specific gravity, thus avoiding any assumption as to the homogeneousness of the piece from which it is cut. There will be in general, however, no need of doing so: thus compare the two following specific gravities obtained—(1) on a piece of paraffin weighing over 11 grms.; (2) on a little disk removed from this, and weighing about ·04 gram. (2) was determined by balancing in dilute alcohol:—

(1) 0·9204
(2) 0·9208

An inappreciable difference of specific gravity.

The disk removed is next weighed in a delicate balance. If as small as described above, the balance should read definitely to 0·2 mgr. Its weight is ω in the equation. It is in all cases manipulated by use of a clean ivory forceps. If very minute it is weighed on a tarred watch-glass, and so need not be manipulated at all after preparation. Removed from the balance, the small fragment (or fragments) of mineral is placed upon the surface of the disk. The extremity of a slip of copper, about 5 mms. wide, is now heated in a smokeless flame—it is better to use a little copper ball, drilled and fitted on to a fine steel knitting-needle—and held above the fragment of mineral, care being taken not to approach it so closely as to endanger the paraffin being volatilized or of its being melted so far as to risk loss by running over. Preferably the disk of paraffin should rest on a piece of wet filter paper, or on an anvil of clean copper; this will keep the lower surface cool. In point of fact, the mineral in general absorbing heat more freely than the paraffin, melts the paraffin beneath it by conductivity, and there is little risk of loss. The heating is continued till the mineral is seen to be completely soaked with the paraffin—every crack and cranny is then filled, the paraffin welling up and swallowing the specimen and expelling all trace of air.

When cold it is placed in the balance and weighed. By subtracting ω from the weight found, we have W, the weight of the mineral.

There is probably no loss of paraffin in this process. Thus it will be found that if such a pellet be very carefully balanced in a solution, removed, dried, and melted on the hitherto unaltered face of the disk, and then replaced in the solution, there is, if anything, a slight decrease of density; on complete cooling this decrease is inappreciable.

The pellet is now dropped into a specific gravity solution. A saturated solution of common salt and water (sp. gr. about 1·2) will in many cases be found sufficient to float it. If so, we have merely to adjust by adding water. Otherwise we resort to Thoulet's solution ("Minéralogie Micrographique", Fouqué et Lévy, p. 118).

I have prepared no pellets approaching this density—2·77—but I prefer the use of this solution in all cases; it seems to concentrate less rapidly by evaporation, and is more "creepy". It should be preserved and reconcentrated by evaporation after use.

In this operation of balancing it is advisable to use a camel's hair-brush for stirring, and also for conveying small quantities of liquid when finally adjusting—a process of much delicacy. The brush is also used for removing bubbles from the pellet, which, however, will be found to give little trouble if the solutions be previously boiled to expel air. If the mixed solutions containing the pellet be left standing for some hours before finally adjusting, it will be found on examination with a lens that bubbles will no longer gather on the paraffin. Should it be desired to preserve the adjusted solution for any little time, the final adjustment should be effected in a stoppered bottle, otherwise concentration will occur in a very short time on exposure to the air.

The last operation is finding the specific gravity of this solution, which gives us s in the formula. This is most accurately done in a Sprengel tube, holding about 5 ccs.; the bottle may also be used.

The following Table records the results of ten experiments, made in verification of the method. I have altogether made but twelve experiments—one was spoiled by overheating and losing some of the paraffin by overflow; the other by inadvertently touching with the heater, and thus drawing off a little paraffin.

I went through with these experiments, and obtained results revealing sensibly the loss of buoyant material.

Thanks to the translucency of the paraffin we are able to examine minutely the appearance and condition of the mineral when imbedded. I have here under the microscope the pellets made up for these experiments. If you will examine with this 1″ objective the appearance presented by the gold of experiment 7, of the cuprite of experiment 10, you will obtain some notion of the efficacy of the melted paraffin to penetrate and surround loose and dendritic bodies. The fragment of cuprite is about twice the size of a pin's head; it is a maze of little exquisite octahedrons, deep blood-red in colour, and with fine translucency. Around it the disk of paraffin is uniformly translucent; through it the paraffin has permeated completely, not a crack or bubble visible. Similarly, the gold seems not less perfectly embalmed beneath its silvery veil—free from any visible blemish to mar the accuracy with which we measure its volume.

Of experiments 4 and 5 it is interesting, perhaps, to note that 4 was undertaken with the notion that the mineral being dealt with was barite. Its weight, as a hand specimen, was deceptive, it being penetrated by sphalerite. On getting the result (2·78) it was concluded that an oversight had been made somewhere in the measurements, and experiment 5 was undertaken; this giving 2·77, the specimen was appealed to. Tests then showed it to be calcite.

I have thought well to include in the Table some of the quantities obtained in working the formula, as bearing on the scale on which the experiments have been made. It is evident that the method can be applied on a much smaller scale still.

TABLE OF EXPERIMENTS.

(Sp. gr. of Paraffin 0·9204.)

	Specific Gravity found.	Specific Gravity (Dana).	Weight of Mineral.	Volume of Mineral.	Weight of Paraffin.	Specific Gravity of Pellet.	OBSERVATIONS.
			Grammes.	*Cub. Cms.*	*Grammes.*		
1. Orthoclase, . .	2·63	2·5–2·6	0·0162	0·00615	0·0674	1·0545	(Co. Dublin.) Very loose and cleavable.
2. Orthoclase, . .	2·66	2·5–2·6	0·0237	0·00879	0·0562	1·1434	(Belleek.) Very loose and cleavable.
3. Magnetite, . .	4·81	4·9–5·2	0·0202	0·00419	0·0654	1·1361	(Krakatoa Ash.) Separated by magnet; contains hypersthene.
4. Calcite, . .	2·78	2·5–3·5	0·0153	0·00547	0·0351	1·1557	(Co. Wicklow.) Foliated.
5. Calcite, . .	2·77	2·5–3·5	0·0201	0·00726	0·0517	1·3967	From same specimen as 4.
6. Tourmaline, . .	2·98	2·9–3·3	0·0128	0·00429	0·0443	1·0973	(Glencullen, Co. Dublin.) Black.
7. Gold, . . .	17·42	15·6–19·5	0·0352	0·00202	0·0322	1·8216	(Peru.) Mossy.
8. Galena, . .	7·21	7·25–7·7	0·0283	0·00392	0·0441	1·3967	Well crystallized.
9. Galena, . .	7·18	7·25–7·7	0·0242	0·00337	0·0258	1·5921	From same specimen as 8.
10. Cuprite, . .	5·81	5·81–6·15	0·0240	0·00413	0·0271	1·5220	Dendritic; crystallized.

VIII.—NOTES ON THE MINERALS OF THE DUBLIN AND WICKLOW GRANITE. I.—THE BERYL AND IOLITE OF GLENCULLEN. By J. JOLY, B.E., Assistant to the Professor of Engineering, Trinity College, Dublin. (With Plates II., III., and IV.)

[Read, November 18, 1885.]

The beryls described in the following pages occur in the granite exposed in the quarries of Glencullen, Co. Dublin, close over the little stream, Cookstown River, which flows into the village of Enniskerry, some three miles further on. These quarries are situated about one mile from the junction of the granite with the schist. Other and larger quarries opened higher up on the same side of the valley yielded, on examination, only one small specimen. In the lower quarries these beryls occur in abundance—an abundance equalled by no other locality in the Dublin and Wicklow granite, so far as I know.

I can find no previous mention of this locality anywhere in published records.[1] In Weaver's remarkable and beautiful work on the geology of Eastern Ireland[2] the locality is unmentioned. Weaver was the first to find beryls in the granite. It is strange that the Glencullen beryls escaped notice so long. The quarries are very old, and beryls have occurred in them, I am informed by the quarrymen, from the first.

The crystals, which are sufficiently remarkable in habit and structure to justify close investigation, occur in veins and bunches throughout the granite, generally coarsely crystallized in their immediate neighbourhood. Orthoclase, especially, occurs in re-

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[1] Prof. J. P. O'Reilly's visit (*Proc.*, R. D. S., vol. iv., p. 505) was made some months after mine, which took place in January, 1885.

[2] "Memoir on the Geological Relations of the East of Ireland," by T. Weaver. From vol. v. of the *Transactions* of the Geological Society of Ireland, 1819. This work is too much neglected: the engravings of mountain profile are exquisite; the letterpress, with all the freshness of "the Complete Angler," is a record of patient and conscientious research.

markably fine crystals. Tourmaline, which most generally is part of the immediate matrix of the more highly altered beryl, occurs plentifully. Mixed with kaolinized matter, it is moulded often in very large masses to the beryl, rarely penetrating the hexagons. I possess, however, a specimen of beryl—from the Ballybetagh quarry—in which a crystal of tourmaline, to all appearance, passes through a well-formed hexagon from side to side. The beryl has been altered, however, which, as we will see, probably affords an explanation.

The beryls of Glencullen present three types: normal crystals, radiating crystals, and altered crystals.

1. Normal Beryl.

Pale apple-green; semi-transparent to translucent. Also yellow; semi-transparent to translucent. Only faces definitely shown, base and prism. The yellow varieties often present, on breaking the crystals across, a core of green-coloured beryl.

Specific gravity = 2·722; taken on a large green hexagon weighing 86 grammes.

Sections of these beryls, taken parallel to prism faces or to basal faces, show numerous enclosures, vitreous with bubble or liquid with bubble; congregated in nebulæ or arranged in strings. These, taken at right angles to optic axis, show want of uniformity in extinction between crossed nicols. There is a cross-hatched appearance, as if the mineral was not crystallographically homogeneous throughout. Des Cloizeau, on optical grounds, considered beryl as probably possessing two optic axes close together.—*Minéralogie*, p. 366, vol. i.

These normal beryls cohabit with muscovite, which often closely adheres over their prismatic faces. In size, crystals measuring a couple of centimeters across the prism face are not uncommon. Some years ago I took a crystal from the small opening in the granite at Ballybetagh, which measured about 4·5 cm. across the prism faces.

Interpenetration by orthoclase is common in these crystals. I have not seen any definitely penetrated by either mica or quartz.

Beryl is not a phosphorescent mineral: if, however, some of these crystals be heated in a dark room they will be found to

become luminous here and there over their surface. This, I ascertained, was due to the fragments of orthoclase adhering to the hexagons. Mr. Moss has been aware of this peculiarity of the Dublin orthoclase for many years, having, like myself, discovered it accidentally.

2. Radiating Beryl.

This second type differs from the first in habit only, but this habit is one not noticed in the descriptive mineralogies, and evidently, at any rate, developed in the crystals found at Glencullen to a rare degree of perfection.

The crystals radiate in the most regular and striking manner, not alone fanwise, but as cones or sphere segments. The prismatic form seems fully preserved in the individual crystals, but each crystal is tapered, dwindling at last to the common centre of radiation. For some distance around this centre no structure, other than radiating lines, is indeed noticeable: further out the crystals individualize, and their prismatic form is apparent. If a chip from near the centre of one of these cones is placed between crossed nicols it is found to extinguish parallel to the radiating lines; hence, the fact that the axis of the prism lies along these lines is almost assured.

A section taken through the centre of a small group of radiating crystals revealed strongly-marked cleavage along the radii, a cleavage at right angles to this also well marked, and faint cleavage lines intersecting at about 100°, this angle being external to the centre, and bisected by the radii. Countless enclosures, mostly vitreous, are present, generally elongated along the radius; these are very minute.

These radiating beryls are pale-green, bluish-green, yellow, and yellow-brown; translucent to opaque, when they are often quite white in colour. Sometimes they are highly altered when they fall under the third type, where they will be described. Basal cleavage cracks cross the radii in lines roughly circular round the centre of radiation. The crystals easily break along this cleavage, producing a stepped appearance along the radii.

The groups are all more or less fan-like in section, that is, the cone seems never to merge into the sphere; they are occasionally

very small, often only a couple of centimeters in diameter, and frequently appear on the surface of the granite in great numbers imparting a very extraordinary appearance to the rock. The figure on plate IV. from a photograph, shows a very lovely specimen full size. It is of a delicate pale, bluish-green colour; translucent. The radii pass through the block of granite removed with it, appearing in coarse, crowded, hexagons on the other side, and mixed with tourmaline. They are there of a rusty-brown colour. Some of the crystals must scale over 15 cms. in length. This specimen was found by Mr. Gerald Stoney, in company with Mr. K. Doyle.

The specific heat[1] of Glencullen beryl, taken by the method of condensation, was found to be 0·21401. The specimen used was a green crystal taken from a group of radiating prisms.

EXPERIMENTS ON LOSS OF COLOUR.

It has long been known that emeralds calcined at a low red heat lose colour, becoming white and opaque, and parting with water and organic matter. Such are the results of Lèwy's experiments, who ascribes the colour of emeralds to the presence of organic matter.

It appeared of interest, as throwing some light on the history of these beryls, and on that of the granite containing them, to repeat the experiment, and if possible fix an inferior limit to the decolourizing temperature.

Experiment 1.—A preliminary experiment on some fragments of green beryl showed that a temperature far below that of red heat sufficed to bleach and render opaque. The fragments were heated on copper foil, over a fire for a few minutes, they could almost be handled immediately on removal.

Experiment 2.—Fragments of green and yellow beryl, dropped into a test tube containing boiling mercury, lost nearly all colour after about one hour's heating.

Experiment 3.—Fragments of green and yellow beryl, sealed

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[1] I hope shortly to publish an account of this method of investigation, and of the means by which I hope to make it generally available.

in a glass tube containing air, and dropped into a tube containing boiling mercury, lost nearly all colour after an hour's heating.

Experiment 4.—Fragments sealed in a glass tube containing air, and heated for five hours to a temperature of 180° C. (in a bath of boiling carbolic acid) suffered no change.

Experiment 5.—Other specimens, heated by means of a sulphuric acid bath to a temperature of 200° C., rising to 250° for about six hours, showed no change.

Experiment 6.—Bits of green and yellow beryl placed in an air bath, retaining a temperature of about 230° C. for thirty hours showed a decided loss of colour.

Experiment 7.—Boiling in water did not restore colour to the decolourized specimens; nor has it returned since (after forty days). The specimens of experiments 2 – 7 retain translucency.

Conclusions.—It appears from experiments 2 and 3 that a temperature of 357° C. (the boiling point of mercury) is sufficient to deprive both green and yellow beryls of colour in a very short time, and that whether in contact with the air or not. Experiment 6 shows that the temperature of alteration may be taken, probably, as well inferior to 350° C.; with long-continued heating possibly below 250° C.

On the nature of the change effected in these beryls by heating I am unable to give an opinion. Their continued translucency shows at any rate that the change is not produced in a mechanical way—as it might be—by the development of very numerous cracks.

I would suggest that this phenomenon bears on the history of rocks containing this mineral. These green and yellow beryls to be found nested far and wide throughout our Dublin granite are in short so many maximum thermometers. Their delicate and beautiful colours indicate a major limit to the changes of temperature experienced by the granite since their formation to the present day.

3. Altered Beryl.

The third type, which may be described as altered beryl, includes the larger portion of the total number of crystals coming from Glencullen. I have found also similar crystals at Ballybetagh and in Killiney granite.

Externally they show well and sharply-developed faces, both prismatic and basal, and the angles of the hexagonal prism. But here the resemblance to beryl ends; they are neither transparent nor translucent. The vitreous surface and homogeneous appearance of beryl are wanting. They are opaque, dull, rough, and piebald: some dull green and white, some dull green and dull rusty brown. They are in fact a different mineral from beryl in all but external form. They are found up to about half a kilo in weight. Sometimes the cores of the hexagons are eaten out into a cavernous tube lined with rusty matter. Occasional cracks crossing the prism recall the imperfect basal cleavage of beryl.

Their specific gravity shows at once that they are not, or only in part, composed of beryl. I found it to be 2·620 taken on a specimen of average appearance, free from hollows, weighing fifty grammes. The lowest specific gravity recorded by Dana is 2·63; by Des Cloizeau 2·67. I have mentioned that the specific gravity of a specimen of normal beryl from Glencullen was found to be 2·722.

The specific heat is hardly abnormal so far as my experiments on beryl go. Three experiments were made on the same specimen used in ascertaining specific gravity:—

(*a*) 0·21554.
(*b*) 0·21446.
(*c*) 0·21691.
Mean specific heat = 0·21563.

On breaking up the crystals they are found to present internally the same appearance as regards colour and lustre as externally.

I have seen no *complete* hexagons of this altered beryl. This is noteworthy. One side or one end of the hexagon invariably passes insensibly into the orthoclastic matrix, that again insensibly passing into granitic mixture with quartz and mica. Tourmaline abuts against the faces in many cases, but is easily peeled off, leaving a clean, smooth surface beneath. It does not penetrate or grow into the prism. With the orthoclase it is different. It is in that case impossible to say, on a fractured surface, where orthoclase begins or prism ends. Nor are these crystals ever found

implanted on quartz only, as is common with normal beryls from Glencullen.

I had a section from one of these crystals prepared for the microscope by Mr. Gregory, of London; it was, by my directions, taken parallel to one of the prismatic faces. The specimen was in colour mottled green and white, with some rusty marks.

On examination in the polarizing microscope it appeared, in the first place, that more than one mineral entered into the composition of these crystals. The fundamental constituents were evidently two in number. There was a constituent presenting the appearance of a felspar, and there was a more homogeneous constituent, which I suspected to be beryl. These were mixed, archipelago-like, in wild confusion, but always quite distinct. The felspathic part extinguished locally or in plumed shadows, which crept over the field as the stage was rotated. Faint cross-hatching, checquered or wavy marks, recalled microcline: these marks appear in fig. 3, pl. III. Such are, however, common in well-authenticated orthoclase. It showed, too, the habitually quiet colours of that felspar, slate-grey in this case; and in fact I had little doubt it was orthoclase. Lately, however, examination of the cavities eaten in these crystals by decomposition has set the question at rest. In these, bunches of small laminate crystals, resembling white orthoclase in appearance, branch from the walls in tufts and plumes; their grouping suggestively recalling the plume-like extinctions obtained on the sections. Fragments of these tufted crystals, removed and placed in a diffusion zone above Thoulet's solution, according to the simple and accurate method devised by Professor Sollas, float side by side with the Glencullen orthoclase. Their specific gravities are, therefore, identical. Again, when compared with Glencullen orthoclase on the Meldometer their melting points are found to be identical. There is little doubt, then, that this constituent is orthoclase.

It is seen at once on the section that this orthoclase includes a great many sharply-defined, brilliantly polarizing crystals, presenting a very beautiful appearance. They are very small, and, with great probability, are iolite.

In the second principal constituent extinction is not local, but takes place simultaneously all over the field, leaving the felspar standing out in luminous veins and patches.—Fig. 1, pl. II. (× 18

diams.) It polarizes in bright colours uniformly, and generally appears limpid and clear, save for conspicuous cleavage streaks. It is bordered where abutting on the felspar, with a dark margin, due to difference of refractive index.

It will be evident that if this constituent is beryl, and the streaky lines alluded to basal cleavage, not only should we expect simultaneous extinction, but we should expect it to occur when these lines are in the plane of analyzer or polarizer, the axes of elasticity of the section being then contained in these planes. On trial it is found to happen so.

Again, in the case of a section cut in a plane at right angles to the one being described—that is, at right angles to the axis of the prism—this same one of the two constituents should behave as if amorphous; that is, remain dark all round between crossed nicols. I had a section cut in this direction from the same specimen, and it behaved as expected, save that it showed the cross-hatched appearance before alluded to as being noticeable on normal beryl so cut. There was no appearance of cleavage.

The analysis subsequently made confirming the presence of beryl, it may be considered certain that this second constituent is indeed that mineral. It contains no iolite.

There is no crystallographic relation discernible in the distribution of these two chief constituents, orthoclase and beryl. Indeed, so far from such being apparent, the felspar seems to wander at random through the beryl; branching veins, sharply defined and often of extreme fineness, spread over the field. Rivers of felspar they look like—now widening into lakes and again dwindling to mere streamlets. Scattered throughout, the iolite glows with exquisite colour, like many-coloured flower blossoms that have fallen and are borne along by a dark river.

Where broadest these veins are sometimes clouded over—a muffed glass appearance—where probably the felspar is kaolinized by water action. There is present also, chiefly through the beryl, a chloritic mineral most nearly resembling Dana's prochlorite in its habit—ropy, radiating, and vermiform. Some of these radiating spheroliths—often extremely minute and closely crowded—show the extinction cross with branches remaining along the sections of the nicols as the stage is rotated, indicative of a structure radiating

along the axis of elasticity. Their colour is dark green to yellow. They are probably an alteration mineral, occurring principally near the surface of the hexagons. To this constituent the dull green colour of the crystals seems to be due. A little pyrites and hematite are also present.

The question that now presents itself for consideration is this:—Here, in the field of the microscope, are two minerals, both in the crystalline state—one true to the external hexagonal form in molecular arrangement, while apparently separated into innumerable isolated portions by the second substance, which, in its optical behaviour, shows no sympathy with the planes which limit in common the extension of both minerals. From our knowledge of its nature, it would indeed be altogether anomalous that it should show such sympathy.

Are we to suppose that we are here dealing with a crystal of beryl which has been eaten into and replaced, at some period of its history, by orthoclase, or with the result of simultaneous intercrystallization of beryl and orthoclase in the first instance?

In favour of this last hypothesis it is to be observed that it is evidently quite unnecessary to suppose isolation of the beryl really to exist, as unnecessary (and indeed obviously more so) as to suppose, when looking at a map, that there was no connexion between the patches of land islanded by the seas. In addition to which, in consideration of the evident harmony of orientation of the beryl molecules throughout, it is unthinkable. As, then, continuity of the hexagonal matrix is in this crystal assured, are we to regard the orthoclase as an inclusion merely—that the clustering laminæ and veins of felspar were formed progressively with the beryl, although no crystallographic relation between the two bodies is visible, or to be expected—that the phenomenon was due to the *compelling power* or hexagonal virtue of the beryl?

Now this compelling power is generally effective in a different way, or to much less extent. It may, indeed, force an abnormal symmetry in a very partial degree on a body crystallizing in juxtaposition: cases of this are known. It may more commonly compel into order the molecular confusion outside the parent crystal: this may be merely growth, or it may give rise to an envelope of smaller crystals of the same species as the parent crystal. It may exert itself by taking up a cloud of fragments already formed, and

give the whole nebula a symmetrical shape as crystallization progresses. This is symmetrical inclusion. The inclusions may be mixed throughout the crystal in such abundance as to relegate the parent crystal to fill the *rôle* of a form-producing paste only; such inclusions might form from the magma as the growth of the parent crystal progressed.

But such of these phenomena as are applicable to the present case would surely be accompanied by confirmatory optical phenomena. Will they again serve to explain the simultaneous stoppage of growth of felspar and beryl?—those large patches of white orthoclase visible over the surface of the hexagons, but perfectly smooth and flush with the prism faces. How did the hexagonal virtue extend its influence to the centre of those areas of the monoclinic mineral? Within, in the cavities, the felspar crystals suggest an independent growth—a growth independent of the hexagonal virtue of their matrix. Had the hexagons ceased growing at that stage, were abruptly-produced faces out of all relation with the symmetry of orthoclase—necessarily so as the laminate crystals are oriented in every direction—to be expected? Elsewhere in normal beryl the felspar behaves after the general manner of inclusions—projects its solid angles out of the beryl, or, if the beryl be sufficiently grown, is swallowed up.

The distribution of the orthoclase in converging veins might also be urged against the intercrystallization hypothesis; but there is a more direct argument forthcoming.

It appeared that if the alteration hypothesis was correct, and if the seat of the attack was to be sought for at the junction of the prism with the orthoclastic matrix, then, in this region, confirmatory phenomena or the reverse might be expected. The continuity of prism and orthoclase has already been pointed out. It appeared highly probable, on the alteration hypothesis, that this junction was the seat of the reaction in the first instance. Subjected to the influence of a potash felspar in a state of hot solution, the beryl was assailed and replaced, it may be at a very slow rate. Such replacement may have been of the nature of alteration merely, the berylium probably being removed, a re-arrangement of the molecules occurring, and the crystalline net of orthoclase replacing the original symmetry.

On these grounds, however vague, I had a section cut from a

well-defined hexagonal prism, close to its junction with the orthoclase, but well within the hexagon, and at right angles to the principal axis of the hexagon.

In this section the phenomena are so eloquent as to set the question at rest. The attack is, in a word, seen at a much advanced stage. The beryl has broken down completely. Uniformity of extinction, which here, if normal, should be persistent between crossed nicols, is no longer seen. Here and there hexagonal forms, left standing by the invading orthoclase, remain quite true to their original position, though veined and worn. These behave as amorphous, save for the cross-hatch marks. Other hexagonal outlines, with angles projected out of 120°, partially restore illumination as they are rotated between the crossed nicols. In short, patches of beryl are found, fallen in the fight, and cut at such various angles with the optic axis, that they can hardly be differentiated by colour or extinction—on the one hand from beryl cut at right angles to that axis, and on the other from beryl cut along that axis.

Fig. 2, Plate II. (× 18 diameters), presents a remarkable picture of dismemberment and solution. The large, broken, and incomplete hexagonal outline there shown was on the alteration hypothesis originally a homogeneous portion of the parent crystal. It is now girdled round with felspar, and broken up. Its cracks are in continuity from side to side. It was even attacked and veined by a primary inroad of felspar before the final attack eat out a path, severing the primary vein and parting the mass. Islands of beryl left standing, or borne down from its banks, mark the course of this felspar flood. More than this, so complete has the final solution been, and so simultaneous all round, that movement of the dismembered hexagon after its isolation is apparent. Thus it will be seen that the edge *a* is no longer parallel to the edge *d*. It is, in fact, according to measurement, about 14° removed from parallelism. This measurement was taken on the photograph; it is then independent of the readings of the angles of the hexagon. Placing now the cross wires of the microscope along the edge *b*, and along the edge *c*, an angle of 132°, about, is scaled on the section. This is fairly concordant with the observation made on the photograph. It should read 134°, to agree with it. There is then evidence of movement of the detached fragments relatively to each other.

It will be noticed in this section that tourmaline is present in tufts and dark masses encroaching on the edge *b*, and generally mixed through the felspar. Elsewhere it is conspicuously of secondary origin to beryl, and my crystal penetrated by tourmaline, before-noticed, is explained by alteration of a similar character to this.

It is to me inconceivable that this jumble of fragments of beryl, with molecular orientation in every direction, scattered through a sea of felspar, owes its external hexagonal form to the hexagonal virtue of the beryl. If, in short, the beryl was not able to keep itself in order, how, on the intercrystallization hypothesis, was it able to shape into order, against their normal molecular tendencies, the molecules of felspar?

What were the nature and circumstances of the reaction which led to this alteration or substitution? Was it hydro-igneous or simply igneous?

It seems probable, in the first place, that intermixtures like this of bodies of very different melting points is most readily explained by hydro-igneous formation of one or both the bodies. Thus Daubrè, by attack with steam at 400° C., obtained crystals of quartz and pyroxene imbedded in an easily fusible matrix, derived from the glass tubes employed.

Other arguments for low temperature origin of the felspar exist. Thus we find a beryl moulded round by felspar: the edges of the beryl are sharp and well defined, although its melting point is far below that of orthoclase.

Again we find the beryl coloured yellow, green, or blue, but it loses all colour, according to experiment, at 350° C., after an hour's heating.

There is internal evidence too. Examined with high powers the sections reveal innumerable enclosures. Some glass, but some composed of liquid, with movable gas bubble. These are plentiful, both in beryl and felspar. In places they range in veins and strings, resembling fluxion structure. Tiny crystals (?) accompany in shoals. With inclined microscope the gas bubbles may often be induced, on tapping the stage, to travel from end to end of the cavity.

It seems probable, then, that the change experienced by these beryls was effected at low temperature, or hydro-igneously. The

pseudomorphous nature of that change is sufficiently accounted for by supposing the reaction as engaging with the beryl only, not with the tourmaline matrix.

In speculating on the circumstances attendant on, and which led to, the reaction, I may be pardoned perhaps for venturing to suggest a theory of the formation of beryl and tourmaline throughout the granite.

The remarkably local nature of the distribution of the beryl in the granite is well known. There are no crystals worth mentioning in the quarries situated close above those in which this abundance of beryl is found. Rochetown Hill is mentioned by Weaver, writing in 1819, as affording beautiful specimens. I searched the quarries recently. The mineral is worked out. I found but one small specimen. In a similar way the Killiney quarries have ceased to yield; they are now represented by Kingstown Pier, where specimens may be found imbedded in the blocks used in its construction. At Ballybetagh a mere opening on the surface yielded a group of crystals contained in a vein of porphyritic granite, which, pursued further down, ceased to yield. The *habitat* of beryl is in short the pocket or the vein, and, when the vein, generally close to the surface.

In all these respects it resembles that other accidental mineral of the granite, tourmaline.

Now it is most thinkable to suppose the rare elements glucinum and boron originally diffused more or less uniformly throughout the region, in which we will suppose the elements of granite to be in a state of slow progressive crystallization in presence of water.

As cooling and solidification advanced, a concentration of those elements would occur, which failed to take part in the molecular arrangements going on throughout the magma, and pockets of highly concentrated mother liquor would be formed.

Many of these pockets, imprisoned at great depths, would retain their position till loss of heat enabled, first, beryl, and then tourmaline, to crystallize out.

Many of these pockets again, as solidification advanced, may be conceived as pressed out, and uniting in one outflow, forcing their way to the surface in cracks left by the shrinking rock; only crystallizing when from loss of pressure, or by conductivity to

the upper and cooler layers of rock, they have attained a sufficiently low temperature.

In these veins the crystals of beryl, forming in deeper and hotter regions than the tourmaline, and taking toll from the passing waters, grow and gather in bunches; the zone of solidification retreating downwards as cooling progresses. Similarly, tourmaline, forming always higher in the vein than beryl, but, like it, ever forming deeper and deeper in the granite, covers up finally with a schorliferous covering the beryl already deposited.

These beryl and schorl veins may be seen in perfection at Glencullen. Sometimes they are euritic in texture: more generally porphyritic, when they yield beryl and schorl, intermingled with overgrown crystals of felspar.

If it is allowable to reason on these lines, it is perhaps sufficient to seek for the cause of the alteration experienced by the beryls in a change of temperature, it may be, of the upwelling waters, whereby dissolution and replacement of the beryl was brought about; or it may be in a change of constituents—more highly alkaline water. Or, finally, both causes may have operated.

Those other changes—cavities eaten out, chlorite developed near the surface of the crystals, kaolinizing of orthoclase and beryl—are most probably changes of tertiary formation. It is probable that water action, at the ordinary temperature, has effected some of these changes. Thus the most advanced cases of decomposition have been taken from the wettest veins in the quarry. I have, from these veins, removed hexagonal shapes, which, crushed between the fingers, crumbled into a rusty-brown kaolin.

Percentage Composition of the altered Beryls.

It is interesting to note the extent to which replacement by orthoclase is carried in some cases. This may be investigated in three ways: by specific gravities, by specific heats, and by chemical analysis.

1. The *specific gravity* of beryl from Glencullen was found to be 2·722; the specific gravity of orthoclase from Glencullen, 2·510. The specific gravity of the mixed minerals was, in the specimen dealt with, 2·625. The weight of this specimen was 50·400 grams.

Neglecting the influence of the small quantity of iolite present, and also the influence of the chloritic mineral, this gives a percentage composition—

Beryl, . . .	54·4
Orthoclase, . .	45·6

2. It is evident from the figures previously given that the *specific heats* will not enable a direct percentage estimation to be made. Thus the specific heat of Glencullen beryl was found to be 0·2140; of the mixed crystal (the same used in investigation by specific gravity), 0·2156; while the following results were obtained for Glencullen orthoclase :—

(*a*) . . .	0·1982
(*b*) . . .	0·1976

giving a mean of 0·1979. Hence, a specific heat lower, and not one higher, than that of beryl was to be expected. In fact, calculating it in the percentages obtained above by specific gravity, the specific heat of such a mixture would be about 0·207. It is remarkable that the large percentage of water (1·4) revealed in the analysis of this specimen will just account for the discrepancy. Beryl normally contains no water, and this orthoclase, by Galbraith's analyses, 0·58 per cent. only. Assuming this as high as 0·3 per cent. of the whole, an abnormal quantity of water, equal to over one per cent., is present. Taking it as low as one per cent., and re-calculating, the theoretical specific heat is found to be 0·2150.

3. According to microscopical examination, orthoclase is the only mineral present which is known to contain an appreciable amount of potash. *Analysis* shows that there is 5·11 per cent. of K_2O in the mixed mineral, the same specimen being used that had served for the previous investigations. Now, as the result of Prof. Galbraith's seven analyses,[1] the felspar of this granite contains 12·2 per cent. of potash. On these data we find orthoclase 42 per cent.

If, however, we calculate the percentage of beryl by the percentage of BeO given below, and by the result of Mallet's analysis of Killiney beryl (he obtained 13·09 per cent of BeO—Dana), so

[1] *Journal of the Geological Society of Ireland*, vol. vi., p. 226.

much as 74 per cent. of beryl is obtained. This suggests that only a small quantity of the oxide was removed in the process of alteration. If we assume 58 per cent. of beryl present, then, on Mallet's analysis, 7·59 per cent. of BeO is to be expected, leaving 2·16 per cent. of that body "free" or mixed through the orthoclase to the extent of 5 per cent. of its weight.

It is also open for us to assume that the deficiency from the normal percentage of BeO for the *entire* mass is due to weathering only; that, in short, *none* of the oxide was removed by the primary alteration; but that the subsequent weathering of the beryl constituent into kaolin and the formation of a chloritic mineral are alone accountable. On this hypothesis the orthoclase would contain about 13 per cent. of BeO. We are, indeed, driven to suppose that alteration had the effect of reducing the percentage of BeO, at all events in some degree; for the examination of these crystals goes to show that it is the beryl constituent which is most readily kaolinized or replaced by chlorite; and the analyses of kaolinized beryl (Dana's min.) reveal a diminution or nearly complete removal of glucina.

The question, however, obviously cannot be discussed on the results of one analysis only.

Analysis of altered Beryl.[1]

Sp. gr., 2·625.

SiO_2	57·73
Al_2O_3	20·06
Fe_2O_3	4·56
K_2O	5·11
Na_2O	1·64
BeO	9·75
MnO	trace
MgO	trace
CaO	trace
Ignition (H_2O)	1·44
	100·29

[1] Made with Mr. W. Early's kind assistance, and chiefly under his directions.

The glucinum, along with some of the iron, was separated from the alumina by carbonate of ammonia, subsequently precipitated by ammonia, and weighed as the oxide along with some iron, which was then estimated volumetrically.

This sample of mixed beryl and orthoclase may then be considered, with little doubt, as containing some 42 per cent. of the latter mineral, and originally some 58 per cent. of beryl. The percentage composition of four other crystals, all showing well-marked hexagonal faces, was also investigated by taking specific gravities.

1. White homogeneous crystal, with beryl lustre. Very hard all over surface.

Weight, 24·803. Sp. gr., 2·69.

Beryl, . .	86
Orthoclase, .	14.

2. Same appearance as 1.

Weight, 9·764. Sp. gr., 2·67.

Beryl, . .	77
Orthoclase, .	23.

3. Piebald crystal. Heterogeneous appearance.

Weight, 20·554. Sp. gr., 2·59.

Beryl, . .	39
Orthoclase, .	61.

4. Same appearance as 3.

Weight, 21·152. Sp. gr., 2.57.

Beryl, . .	30
Orthoclase, .	70.

These computations assume the specific gravity of beryl as 2·722; of orthoclase as 2·510. It is to be remembered that other values are assignable, but that these seem fairly well borne out by the analysis.

Briefly summing up the results of these various observations, it appears, with great probability, that the heterogeneous crystals were primarily composed entirely of beryl: subjected secondarily to reaction with a potash felspar in a state of hot solution, they were partially replaced, and that to very different degrees; that the primal seat of this reaction is, in general, traceable to one region of the crystal, now the implanted surface, in which direction the replacement is most complete, the original structure of the crystal being often completely broken down; and that this reaction, being confined between beryl and felspar, allowed of the hexagonal form being preserved within the schorlifferous matrix, the result being a variable mixture of felspar and beryl pseudomorphous after beryl. The felspar so mixed with the beryl is orthoclase, containing a mineral in general foreign to Irish rocks, iolite, and, further, containing, there is reason to believe, glucina; but this question is not gone into in the present Paper.

Subsequently, and probably as the effects of hydration, the mixture has been kaolinized to variable extents; and, as a tertiary alteration also, a chloritic mineral has been formed through the beryl.

The beryls of Glencullen often radiate in beautiful conical bunches, with a completeness and regularity not noticed in descriptive mineralogy.

These are often of delicate green and yellow hues; and such, in common with crystals of normal habit, lose nearly all colour after being exposed for a short time to a temperature of about 350° C.

The Iolite of Glencullen.

I now turn to the consideration of the very minute crystals developed through the felspar, and absent from those portions of the sections composed of beryl.

The crystals appeared in two types:—a wide polygonal form, often with twelve edges, extinguishing along two edges situated at right angles to each other on the polygon; a rectangular elongated form, extinguishing most generally along the edges, but often at variable angles with the edges. Foliation in thin plates

was common over the surface of the polygonal form: cleavage was generally parallel to the ends of the rectangle in the rectangular forms.

On first approaching the subject, I formed the hypothesis that some of the symmetrically extinguishing rectangular forms were beryl cut parallel to axis of prism. The absence of hexagonal sections threw doubts on that hypothesis. Some of the other rectangular forms I thought were orthoclase developed on the zone *ph′* (Levy). Such a zone shows large base, rectangular, with extinctions parallel to sides; orthopinacoid large, with extinctions parallel to sides; clinopinacoid small, with extinctions parallel to sides in "orthose *non-deformè*," at 5° in "orthose *deformè*." But this zone should show, when cut squarely, the axial angle of 63° 33′. It was never found thus in the sections. The colours of polarization, too, were not those of orthoclase.

It was evidently possible, also, to account for the appearances by supposing the crystals orthorhombic, in which case, further, both forms might be supposed to be different views of one and the same crystal.

Now the angles of the polygon were all about 150° when twelve-sided; and in eight-sided figures, not uncommon, one set of faces produced intersected at 90°, another at 60° and 120°. To what orthorhombic mineral were such angles to be assigned? Not being acquainted with any such, I had set the mineral for the most part down as "doubtful," with the suggestion that some of the forms might be orthoclase, when I had recourse to an apparatus I devised about this time for investigating the melting points of small fragments of minerals. This apparatus is briefly described in *Nature* (vol. xxxiii., p. 15), where I call it a "meldometer," or measurer of melting points. By the help of this apparatus I differentiated them from every substance I had ever suspected as being present. I must explain, however, how I succeeded in obtaining the crystals isolated and free of the matrix.

I mentioned before the cavities eaten by decomposition in the large hexagonal crystals of mixed beryl and orthoclase. These cavities appeared filled in part with a rusty-brown powder, and in part with a frail skeleton of hard matter (felspar) clinging to the walls or loose in the cavity. On removing this *debris*, crushing

the lumpy parts, washing and cleaning in boiling hydrochloric acid, clear, glassy crystals, of extremely small size, appeared in countless numbers through the residue. These, mounted in Canada balsam, proved to be the identical crystals visible in the sections—some beautifully sharp and clear, some partly decomposed and overspread with a filiform, branching growth of olive-yellow colour. Micrometric measurements gave 0·1 mm. as the length of the larger specimens showing good angles. With such dimensions it was difficult to deal with them singly.

Again, by breaking up the hexagons and crushing the felspathic matrix containing these crystals, treating carefully with hydrofluoric acid, specimens were obtained fairly clean. But the first source, where decomposition had removed the beryl and some of the orthoclase, but had spared the small sharp crystals, was my great source of supply. In these hollows slow-acting decomposition has effected a fairly perfect isolation, and I have opened cavities from which the tiny crystals could be *poured* in great numbers, only requiring cleansing from their rust-coloured coating to be ready for the microscope.

The slides composed of these crystals present a spectacle of such perfection of form, and, in the polariscope, such richness of colour, as would far surpass any power of description. Feeling this, I will, instead, refer the imagination of my reader to the soft crimsons, purples, and tender blues of those cloud islands and vistas seen at sunset, where the colour is not the dead brightness of opaque reflection, but is living with transmitted light. And I would remind him, that while in that case the imagination is affected by the far-off peace of those regions to clothe them with an unreal richness and tenderness of tint, these children of the rocks are not so seen with the eyes of dreamland. I will ask him, then, to picture a precision of form and matchless depth of colour which, to none but the scientific imagination, are as breathless objects of adoration, as the infinite oceans of sunset.

Having obtained the mineral thus isolated from its matrix, it was resolved to treat some of the little crystals on the meldometer along with orthoclase, and also compare their behaviour at high temperatures with topaz, quartz, &c. I had only just begun to use the apparatus, and was desirous of testing its value as a means of differentiation; for although no determinations of melting points

were obtainable to render numerical results of value, yet the comparative test was easily applied, and would probably throw some light on the nature of the mineral.

Comparison with Orthoclase.—The orthoclase used was from Belleek, and also from Co. Dublin; respectively red and white in colour—subtranslucent. The unknown crystals were transparent and colourless.

The orthoclase fused first, and gathered into transparent beads of glass containing large bubbles. At a much higher temperature the unknown mineral rounded and turned milk-white in colour, developing no bubbles.

The experiment was more than once repeated. The unknown mineral had evidently a much higher melting point than orthoclase, and its behaviour in other respects, also, differentiated the two substances decisively.

Comparison with Topaz.—Fragments of clear topaz and the unknown mineral. Both rounded simultaneously, and both turned milk-white. The topaz, however, emitted a gas which raised blisters and blue bubbles on the melting surface of the fragments. On the breaking of these bubbles, threads of glass were thrown about the hob, and the gas attacking the platinum deposited rings of colour around. Probably the gas contained in these bubbles is fluorine, liberated at the high temperature employed. The coloured rings, fluoride of platinum. No such phenomena occurred with the unknown mineral. They probably contained no fluorine.

Comparison with Quartz.—Clear rock crystal showed a much greater resistance to the temperature of the hob, only fusing at the extreme limit of endurance of the platinum itself.

The melting point of the unknown mineral was therefore fixed as above that of orthoclase, and below that of quartz.

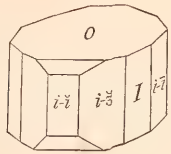
These results, together with the knowledge of its angles already gathered from the microscope, led me to think for a time that I might be dealing with a new species. More accurate crystallographic measurements were desirable.

By manipulating one solitary crystal, obtaining extinctions along its faces, and measuring its angles, its orthorhombic character, both by symmetry and elasticity, was determined beyond doubt.

Its specific gravity was now taken by Professor Sollas' method. It was found to be 2·58.

DICHROIT, IOLITE, CORDIERITE.

ORTHORHOMBIC.



$I \wedge I = 119^\circ\ 10'$ and $60^\circ\ 50'$

$I \wedge i\text{-}\breve{3} = 150^\circ \quad i\text{-}\breve{\imath} \wedge i\text{-}\breve{3} = 150^\circ\ 25'$

$i\text{-}\breve{3} \wedge i\text{-}\breve{3} = 120^\circ\ 50' \qquad O \wedge I = 90^\circ$

Cleavage, $i\text{-}\breve{\imath}$ distinct; $i\text{-}\bar{\imath}$ and O indistinct. Fracture, sub-conchoidal.

Crystals, foliated parallel with O. Twins, composition face I.

Transparent.
Dichroic, blue to yellow, but feeble in small crystals.

Lustre vitreous.
Colour, blue shades.

Spec. grav. = 2·59

Hardness = 7–7·5
Fuses at 5·5, loses transparency.

Chemical Composition (Mean).

Silica, SiO_2,	50·0
Alumina, Al_2O_3,	31·6
Ferrous Oxide, FeO,	6·6
Magnesia, MgO,	10·4
Calcium Oxide, CaO,	0·6
Manganese Oxide, MnO,	0·4
Ignition, (H_2O),	1·4

ORTHORHOMBIC.

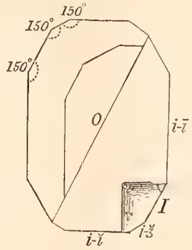


FIG. 1.

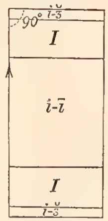


FIG. 2.

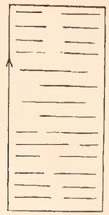


FIG. 3.

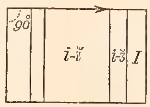


FIG. 4.

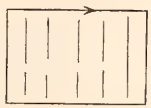


FIG. 5.

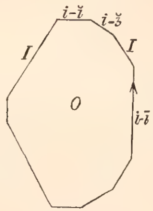


FIG. 6.

Transparent.
Dichroism uncertain.

Lustre vitreous.
Colour, pale blue.

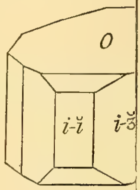
Spec. grav. = 2·58

Hardness about 7.
Fuses with Iolite, turns opaque white.

Analysis of Impure Specimen.

56·7
20·7
13·9
4·2
trace
trace
2·0
97·5

ORTHORH



$I \wedge I = 119° \, 10'$ and C

$I \wedge i\text{-}\breve{3} = 150°$ $\quad i\text{-}\breve{i} \wedge$

$i\text{-}\breve{3} \wedge i\text{-}\breve{3} = 120° \, 50'$

Cleavage, $i\text{-}\breve{i}$ distinct; $i\text{-}\bar{i}$ and O indis

Crystals, foliated parallel with O.

Transpar
Dichroic, blue to yellow, but

Lustre vitr
Colour, blue

Spec. grav. =

Hardness =

Fuses at 5·5, loses

Chemical Compos

Silica, SiO_2, . . .	
Alumina, Al_2O_3, . .	
Ferrous Oxide, FeO, . .	
Magnesia, MgO, . .	
Calcium Oxide, CaO, .	
Manganese Oxide, MnO, .	
Ignition, (H_2O), . .	

The characteristics ultimately determined are recorded in the annexed Table, in the right-hand column. The characteristics of Iolite, the Cordierite of the French school, appear in the left. Taken collectively the evidence is, I think, irresistible that these small crystals are iolite.

Figure 1 on the Table, right-hand column, depicts the basal face of the crystal. It shows foliated habit and twin-line, or trace of composition plane I.

The angles I had in the first instance determined as the mean of many measurements were so close to 150° each, that I decided to enter them as such. This gives nearly the same values as Dana and others record: $I \wedge I$ is 120° and 60°, and the secondary face in the zone II becomes nearly $i - \breve{3}$.

Extinction is along $i - \bar{\imath}$ and $i - \breve{\imath}$, shown by the arrow-head. The face $i - \breve{3}$ is often absent, and always small. Fractured corners, as in fig. 1, are common. The cleavage is then well seen.

Figure 2 is elevation of zone II. Extinction, as shown.

Figure 3 is section on $i - \bar{\imath}$, showing cleavage.

Figure 4 is end-elevation of zone II.

Figure 5 is section on $i - \breve{\imath}$. Cleavage very obscure, or absent.

Figure 6 is a hemihedral form respecting $i - \breve{3}$; not very uncommon.

Looking down the column, I need only observe that the *colour* is only seen when a large number of crystals are superimposed, as in a narrow test-tube, and viewed by transmitted light.

The *hardness* was only very approximately determined by pressing a number of the crystals into the end of a lead wire, and then, using the wire as a handle, proceeding as usual.

The *fusibility* was determined to be about the same as iolite by comparison with an authenticated specimen on the meldometer. It is perhaps a little higher than that of the specimen used; nor did the known iolite whiten to any great extent. The loss of transparency experienced by iolite on fusing is however well known. Lime is generally present in this mineral: its absence might account for exceptional behaviour in this respect.

An analysis, made with Mr. Early's assistance, is added. The material for this was obtained as follows:—The powder obtained from the hollows in the hexagons was boiled for a few minutes in strong hydrochloric acid, and thoroughly washed in water:

separated from free quartz, orthoclase, and tourmaline, by Thoulet's specific gravity solution. The crystals thus obtained were freed of large mixed fragments and very fine particles by descent through a long column of still water;—a method described by me elsewhere (*Proc. R. D. S.*, vol. iv., p. 291). The large rough fragments so removed were found on microscopic examination to be very impure, the medium-sized crystals fairly pure, the fine dust very heterogeneous and impure. A few of the larger of the medium-sized crystals being sorted out for photographing and mounting, the remainder, weighing about two decigrammes, was devoted to analysis.

The percentages obtained in the analysis hardly approximate to the numbers for iolite given in the left-hand column. This was to be expected from the impurity of the sample. The presence of 4 per cent. of MgO is, however, important, as there was probably no source of impurity present capable of affording an appreciable weight of that body. I think it highly probable that glucina may enter into the composition of these crystals, replacing the magnesia, the elements Be and Mg being isomorphous. Glucina was not looked for in the analysis. *It is remarkable that these crystals seem present only in orthoclase, thus intermixed with beryl.* In other sections of Glencullen orthoclase, as well as in sections of granite[1] from Co. Cavan, Co. Mayo, Newry, Killiney, Warrenpoint, and from the Mourne Mountains, I could detect none of these crystals. As in the case of their felspathic matrix, I have little doubt of the correctness of my diagnosis of the mineral species. Whether perfectly normal in chemical composition or not, can however only be decided by further and more careful analysis.

The formula to be deduced from the analysis, such as it is, is—

$$10\,SiO_2 \,.\, 2\,(Al_2O_3 \,.\, FeO) \,.\, MgO \,.\, H_2O,$$

which, be it observed, affords a bisilicate oxygen ratio, instead of a unisilicate ratio.

As a microscopical mineral, this iolite will be recognized by its basal angles of 150°, 120°, or 60°; its generally symmetrical extinction on elongated rectangular sections, and the transverse cleavage on such sections. The foliation, or plating on O, and the oblique

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[1] Kindly lent by Professor Hull.

twining line parallel to *I*, are also frequently met with. Occasionally the crystals occur in radiating groups. When thus arranged, it will be found that the basal faces have a sort of symmetrical arrangement, being all oriented into planes perpendicular to the plane of radiation, so that it is seen as radiating in rectangular forms only. I may also observe, that so minute are these crystals that they are freely contained and propped into every conceivable position within the small thickness of the section. This fact, coupled with the simultaneous focus of pinacoid, or prism faces, on opposite sides of the plane of symmetry, renders necessary considerable caution in deciding on the nature of the forms in the field.

The angles are generally sharp. Enclosures are rare ; generally glass. Mutual interpenetration is very common. They present all the appearance of having been formed antecedently to their felspathic matrix. Colours are generally exquisite, but they will, of course, vary with the thickness of the section in the field. Pale-grey forms are not therefore to be put down necessarily as felspar—they are not uncommon. The dichroism is too feeble, seemingly, in such small crystals to be of value in diagnosis. Branching veins of a translucent greenish decomposition product cover the faces in some cases. Iolite is known in many decomposition forms.

Figure 4, plate III., is a photograph showing a group of iolite crystals sorted from those prepared for analysis, as described. They are exceptionally large specimens. Enlargement, 18 diameters.

Figure 3, plate III., more highly magnified ($\times$ 70 diameters), shows iolite *in situ*. A polygonal form, slightly turned up, so as to show the faces $i - \check{\imath}$ and I conspicuously, as well as the basal face O, occupies the centre of the field. The other forms are mostly rectangular, parallel, more or less, to the face $i - \check{\imath}$. Some of these show the $i - \check{\imath}$ cleavage. They nearly all extinguish longitudinally. The chequered appearance of the felspar is displayed over the field.

EXPLANATION OF PLATES II., III., AND IV.

Plate II.

Figure 1.—Veins of Felspar traversing Beryl. Section through a crystal of altered Beryl, parallel to axis of hexagonal prism. Light polarized. (× 18 diameters.)

Figure 2.—Broken down Beryl. Section near base of mixed Beryl and Orthoclase. Light polarized. (× 18 diameters.)

N.B.—As the letters have been omitted, the edges referred to may be identified thus :—lowest left-hand edge (about one centimetre in length) is the edge *d* ; the adjoining edges *c* ; the uppermost edge broken by the fissure is *b*, and the next adjoining edge is *a*.

Plate III.

Figure 3.—Iolite *in situ*, showing markings of Orthoclase. Section in altered Beryl.

Figure 4.—Group of Iolite crystals removed from cavities in mixed Beryl and Orthoclase. Light polarized. (× 18 diameters.)

N.B.—The description of these two last figures has been transposed on the Plate.

Plate IV.

Figure 5.—Radiating Beryl in granite matrix.

IX.—NOTE ON THE ARTIFICIAL DEPOSITION OF CRYSTALS OF CALCITE ON SPICULES OF A CALCI-SPONGE. By PROFESSOR SOLLAS, D. Sc.

[Read, June 15, 1885.]

SOME acerate and triradiate spicules of a calci-sponge, after having been left to stand for some days in water containing an excess of calcium carbonate, were found to have become incrusted with an abundant crop of minute crystals of calcite. The exact form of the crystals was not ascertained; but, as on rotation between crossed Nicols, they extinguished simultaneously with the spicules on which they were seated, and underwent the same changes in refractive index, we may conclude that the optic axes of the calcite forming a spicule, and the crystals incrusting it, are similarly orientated.

A curious feature in the distribution of the crystals is worth notice. They do not cover the whole of a sagittal triradiate, but are confined to opposite sides of the paired rays and the extremity of the unpaired ray; an acerate, is, however, often covered with them for its whole length, but usually only on opposite sides. Thus the crystals are deposited only on those regions which show the greatest liability to solution:[1] thus it would appear that the polarity which leads to solution also determines deposition.

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[1] *Vide* Sollas, on "Physical Characters of Calcareous Spicules," &c., *Proceedings Royal Dublin Society*, vol. iv., N. S., p. 385.

X.—THE DOUBLE QUADRIFORM LIGHTHOUSE LAMP. By PROFESSOR W. F. BARRETT.

[Read, December 16, 1886.]

It may be of interest to lay before the Members of this Section of the Royal Dublin Society some observations which I have recently had the opportunity of making upon the fog-penetrating power of the new system of lighthouse illumination devised by Mr. J. R. Wigham, of Dublin.

As Professor Tyndall has remarked in a recent letter to *The Times*, when Mr. Wigham began his experiments the best lighthouse lamp in general use was the four-wick oil-lamp, and the augmented illuminating power in lighthouses which exists at the present day is very largely due to the competition which Mr. Wigham's superior light has called forth. As is well known, Mr. Wigham is the inventor of gas illumination for lighthouses, and the adaptability of gas for this purpose has enabled him to build up a series of three, four, and now eight lights, with their appropriate lenses, within one lighthouse. The high temperature within the lantern produced by so many lights has not, I understand, in any of the trials made in Ireland, been found to be dangerous to the lenses, and whilst a high temperature is favourable to the illuminating power of coal-gas, it would, I imagine, be fatal to the employment of mineral oils instead of gas. The latest and most powerful arrangement which Mr. Wigham has made is the so-called Double Quadriform light (figs. 1 and 2). This consists of four superposed 88-jet gas-burners (B.B., &c.) placed alongside of four similar superposed sets, the eight lights being in one plane: parallel to this plane, and at the proper focal distance, are placed eight annular lenses on one side, and eight similar lenses on the other side of the gas-burners. Over each of the burners a chimney is fixed; these lead into a central flue, C, so arranged that no appreciable interference with the light is produced. The recent experiments made at South Foreland show that similar superposed lights blend into one within 1500 feet from the lighthouse; and when this occurs

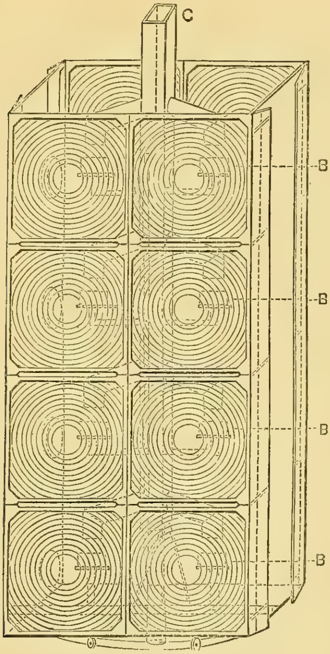

Fig. 1.
General View of Apparatus.

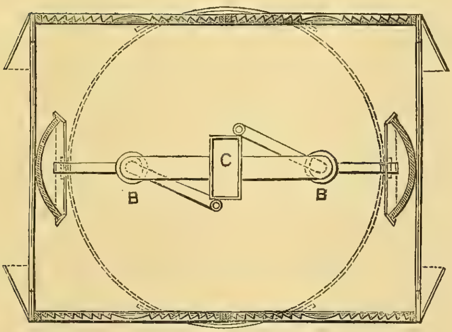

Fig. 2.
Section through Focal Plane.
Scale—¼ inch to a foot.

a beam of eight-fold the intensity of a single light is obtained from the Double Quadriform.[1] An ingenious contrivance allows the whole arrangement to be rotated without disturbing the gas supply; thus the entire horizon can be successively illuminated with a beam of light of surpassing power.

The Commissioners of Irish Lights have for some months past been testing this new Double Quadriform light, which they have had erected in an experimental house at Howth Head, some 100 yards distant from the Bailey lighthouse, the well-known powerful first-order light at the entrance to Dublin Bay. The Bailey, it may be mentioned, is also a gas lighthouse that can, by the addition of concentric rings of burners, be rapidly raised when fog prevails from 28 to 48, 68, 88, or 108 jets. Alongside the Bailey light is a powerful siren trumpet, driven by a gas-engine, and blown by compressed air at minute intervals during heavy fogs.

It so happened that on both the evenings when I had arranged to observe the new light a fog had settled over the Bay of Dublin. My position of observation was near my own house at Monkstown, where, in clear weather, an uninterrupted view over the bay can be obtained, my standpoint being distant *six miles*, as the crow flies, from the experimental lighthouse.

Evening of November 18.—Owing to the intervening fog no trace of the Bailey light could be seen, though its position was well known. The first experiment was the trial of a series of gas-jets fed with "albo-carbon" vapour and oxygen, placed in the focus of a first-order annular lens, such as is used for revolving lights. Brilliant as was the light so produced, it was completely cut off by the fog before it reached me, though the beam was directed on to the position I occupied. With a large opera glass I was however just able to make out the light, and saw also the Bailey near it, as a fainter speck of light. Suddenly, at the prearranged time, a clear well-defined pillar of light sprung into view, *easily visible to the naked eye*, and appearing as a large distinct light through the glass. This was the Double Quadriform. In ten minutes, as had been arranged, that was extinguished: complete darkness again covered the horizon. With great difficulty, and

[1] The South Foreland experiments were made with a light of half this power.

only by the aid of an opera glass, the Bailey light was occasionally found.

After another interval the Double Quadriform was again lighted, and this time made to revolve. As before, it was a striking object to the naked eye, arresting the attention at once, and the period of its revolution was easily noted by the unaided eye.

Evening of November 23.—This night the experiments were repeated under still more crucial conditions. A much thicker fog, with drizzling rain, hid all lights from view except those near at hand. Even the two fine lights at the "Poolbeg," one of them a first-order revolving oil light, were completely obscured, though these lights were less than half the distance of the experimental light. The Bailey light itself was entirely cut off, and could not be picked up even with a powerful glass. It was then burning, as I learnt next day, its maximum light of 108 jets. Not the faintest trace of the fog siren at the Bailey could be heard, though, as afterwards ascertained, it was sounding with its full power during these experiments. Precisely at the time appointed for the lighting up of the Double Quadriform a sudden glare was seen on the horizon. With the opera glass the shape of the light was easily defined, but no trace of the adjacent Bailey light could be found, even after the most careful search through the glass. There were in all 632 gas-jets burning, and as these, by prearrangement, were raised and lowered, a flashing light was produced readily seen by the naked eye. The double triform arrangement was next tried: this could be seen faintly with the naked eye. The biform was now tried, but this was invisible even with the glass. This is important as showing the advantage of the multiple lights; for, in this experiment, the character of the lights and lenses were the same as the double quadriform, only of one-fourth the total power. The double quadriform was again put on, and, as before, its glare was at once seen and its position determined with the naked eye, the exact quadrangular shape of the light being easily made out with the glass. All the other lights remained utterly invisible, even with the aid of a good glass and a knowledge of their exact position.

I cannot but think that the facts here recorded are worthy of attention. They demonstrate that the double quadriform arrests the attention, as a conspicuous glare to the naked eye, and as a clearly-defined object in an opera glass, through a fog of suf-

ficient depth and density to cut off a first-class light shining through an annular lens at half the distance, and to quench the sound of a fog-siren adjacent to the double quadriform.

It would have been important to have made a comparative experiment with a single electric light of similar intensity, having its beam concentrated by a single annular lens. There were, however, no means of trying this. The recent elaborate Board of Trade investigation at South Foreland led the eminent men of science who conducted the inquiry to the conclusion that the electric light has a slightly greater penetrative power in fog than the triform oil or quadriform gas-lamp with which it was compared, the two latter being practically equal, light for light, in all conditions of weather.[1]

Nevertheless, it is much to be desired that some representatives of the Trinity Board, or of the Board of Trade, should, whilst the double quadriform is in its present position, come over to Dublin, and in foggy weather test a gas-light twice as powerful as any they have yet tried, and under conditions exactly similar to those which prevail in the practical use of the light at sea.

No doubt, the cost of the double quadriform light is considerable, both as regards initial expense and consumption of gas. On the other hand, it must be borne in mind that a powerful light of this kind is only intended for the more important points on the Coast, and it is only under exceptional conditions of fog that the full consumption of gas need be resorted to. Moreover, as Mr. Howard Grubb, F.R.S. (who, independently of myself, has recently tested this new light), has remarked in his Report:—"Economic considerations fade into insignificance before the one broad fact that, when occasion does require a powerful light, this arrangement of Mr. Wigham's gives the power of producing a revolving light unequalled by any existing arrangement."

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[1] These conclusions, however, seem to be contradicted by, at any rate, one observer (p. 29 of the Report), who, after comparing the lights in "drizzling rain and dense fog," remarks: "In honesty, I award *B* [that is, the quadiform gas], the most points, for I consider it the best light from first to last."

XI.—ON A CLOGG ALMANACK IN THE SCIENCE AND ART MUSEUM, DUBLIN. By BENJAMIN H. MULLEN, B.A., Dub. (Plate V.)

[Read, December 16, 1885.]

For many years past this Clogg has been in the Museum, and my attention was first drawn to it by Mr. T. H. Longfield, who had seen somewhat similarly carved sticks in the British Museum exhibited as Norwegian. This account has been prepared and the Clogg figured with the permission of the Director of the Science and Art Museum.

It is made of oak, and in length is 1 ft. 8 in., while its breadth is $4\frac{3}{4}$ inches. It is in shape a rude and long oval, flat, and from $\frac{3}{8}$ to $\frac{1}{2}$ in. thick. The centre portion was cut away, thus leaving four edges (two inside and two out) and four flat surfaces. Two holes for suspension were cut, one at either end; but these were made in a gnarled part of the wood, and it would seem that at some period of its existence it was broken at this weakened part, and bound together again with two fastenings of iron, of which one only remains. At one end there is some carved decoration. This is a very simple design, being merely a line cut into the wood at a distance of about a quarter of an inch from the edge, and running parallel to it; having at each side of it notches cut in a triangular form; while in the middle are the initials "S. E." Beyond what I mention, there is no ornamentation whatever.

Almanacks of wood have, I gather, being used from time immemorial.

Dr. Robert Plot, in his *Natural History of Staffordshire* (folio, 1686), speaks of "An ancient sort of almanacks they call cloggs, made upon square sticks, still in use here among the meaner sort of people, which I cannot but think must be some remains of the Danish Government, finding the same with little difference to have been used also formerly both in Sweden and Denmark, which being a sort of antiquity so little known that it hath scarce been yet heard of in the southern parts of England, and understood

now but by few gentry in the northern." He tells us that "there are some few of brass . . . but the most of them of wood, and these chiefly of box; others there are of fir, and some of oak, but these not so frequent . . . and others inscribed in a hollow bone. . . . All people, no question, made them of such materials as they thought fittest for their purpose." And as to their sizes, he says "there are some public, of a larger size, which hang commonly here at one end of the mantletree of their chimneys for the use of the whole family, and others private, of a smaller size, which they carry in their pockets." He gives a sketch of one which was "in use in his native country of Staffordshire" at the time he wrote.

The usual form was that of a razor-strop, some having four equal surfaces, and others being about 2 inches wide and ½ inch thick. The former, probably a later form, bore the marks for a quarter of the year on each surface; and the latter had the days of half the year on each side. Some were of an elaborate description, showing the Moon's Changes and the Golden Numbers; but few were so perfect. They were first made centuries before the invention of the printing-press, when a vast majority of the people were unable to read, and were probably originally employed in connexion with the churchmen, to whom, in early times, learning was confined. It is likely that one was kept in a public place in every parish or hundred; and later, one might be found in every house, suspended by a cord or ring, or hung on a nail beside the fire-place in the hall or principal room, where every member of the household might use it.

The days were marked on the edges by notches; and every seventh day was indicated by a longer notch; while Holy Days and Saints' Days were denoted by signs (peculiar to the occasion) on the flat surfaces, proceeding from the notches in the edge.

I cannot find that cloggs similar in outline to that in the Museum were usual. A cursory glance at it would lead one to imagine that it is of some antiquity. In the first place, its shape is very inconvenient for handling. The squared staff with a handle is much less so; and I merely follow the laws of development in assuming that the improved form is of a date posterior to the other. And again (what much more surely goes to prove the local earliness of this class of clogg) the symbols which represent the

Saints' Days and Festivals are not numerous, nor are the daily notches always correct. A reasonable way to account for this is that when it was made such almanacks were not in very general use, and the signs to denote the different saints not being hitherto necessary were, with a few exceptions, unknown—at all events in the locality in which this clogg was made.

The four edges are notched evenly and cleanly, and evidently with a sharp instrument, for in all cases the notches are made by two oblique incisions. The Sunday notches are carried round to one surface, and the signs to the other.

Before I go *seriatim* through the principal days, I wish to say that in identifying the Saints' Days I have received much valuable assistance from a Paper by Mr. John Harland, F.S.A., published in 1865 in *The Antiquary.*

The Almanack does not begin with 1st January, but with 14th April, which was reckoned as the commencement of Summer.

The carving and initials I mentioned are here, and this alone would lead one to imagine that it is here the reading of the clogg begins. And from the position of the letters "S. E." this carved end must be the top. Each quarter reads downwards; the first, from 14th April (Pl. v. fig. 1), goes down the left half for thirteen weeks; then, turning the stick (fig. 2), it continues on the same half (now at the right hand) from 14th July for another quarter; crossing to the other half it goes (always reading downwards) from 14th October for the third quarter; and, again turning (fig. 1), the fourth quarter is read from 14th January.

Beginning with *April 14,* I find a tree, Valerianus; *April 16,* St. Magnus, sign, probably some implement for loosening the soil, to signify the commencement of tilling; *April 25,* St. Mark, an unknown sign shaped like a bottle; *May 1,* SS. Philip and James, a cross, one arm wanting; *May 3,* Invention of the Cross, a cross; *May 14,* an unknown sign, perhaps some local festival or family commemoration; *May 15,* St. Hallvard, a cross; *May 18,* a scythe: the first hay crop would be about this time; *June 10,* Eve of St. Barnabas, a cross; *June 17,* St. Botolph, a cross; *June 24,* St. John the Baptist, a cross; *June 29,* St. Peter, a sign, probably meant to represent a key (Janitor); *July 2,* Visitation of the Virgin, a three-branched candlestick; *July 8,* a "T" or rake. This is the last sign in the first quarter; but there is one day too

many which, if it occur before the *8th*, would bring the "T" to the *7th*, the Translation of St. Thomas à Becket; or, occurring after, the sign would mark St. Sunniva (*July 8*), a great holiday.

Turning the clogg, I find on *July 14* an unknown sign, the middle of the summer-half; *July 20*, St. Margaret, a cross; *July 22*, St. Mary Magdalene, a cross leaning to one side, perhaps to show its position when being borne by our Saviour; *July 25*, St. John the Apostle, an unfinished sign, the previous one being in the way; *July 29*, St. Olaf (Danish King and Saint), an axe; *August 3*, the day on which his body was found, a smaller axe; *August 10*, St. Lawrence, a gridiron, signifying the manner of his death; *August 15*, Assumption of Mary, a three-branched candlestick; *August 24*, St. Bartholomew, a sign shaped like a knife; *September 1*, St. Giles, a cross; *September 8*, Nativity of the Virgin, an unknown sign; *September 14*, Exaltation of the Cross, an unknown sign; *September 29*, St. Michael the Archangel, a peculiar sign like a vane or rude balance: this day is not far past the Equinox; *October 4*, St. Francis, a simple cross. October 13th ends this quarter.

Crossing over to the top of the other half, *October 14*, St. Callistus, a fir-tree; *October 21*, 11,000 Virgins, a cross; *October 28*, SS. Simon and Jude, a cross; *November 1*, All Saints Day, a three-branched candlestick; *November 11*, St. Martin, a cross, with a second on one arm; *November 18*, a rude cross or sword; *November 23*, St. Clement, a cross; *November 25*, St. Catherine, a cross; *November 30*, St. Andrew, a cross; *December 4*, St. Barbara, a sign of unfinished appearance, probably on account of the close proximity of the next; *December 6*, St. Nicholas, a cross; *December 8*, Conception of the Virgin, a cross; *December 13*, St. Lucy, a cross; *December 21*, St. Thomas, a long line, possibly meant for a spear; *December 25*, Christmas Day, a circle with radiating points, very likely to represent the guiding star; *January 1*, Circumcision, a circle with a line running through it; *January 6*, Epiphany, a cross; *January 11*, St. Brictiva, a cross; *January 13*, St. Hilary, twenty days after Christmas, an unknown sign, similar in form to that on July 14, and probably marks mid-winter, as the latter did mid-summer. This ends the third quarter, and turning the clogg I come to the last.

Here is one mark too many. *January 17*, St. Anthony, a

cross; *January 20*, St. Sebastian, a cross; *January 25*, Conversion of St. Paul, a cross; *February 2*, Purification of the Virgin, a cross; *February 3*, St. Blaise, a very rude cross; *February 24*, St. Matthias, a cross; *March 12*, Annunciation of Mary, an erect cross, with a "St. Andrew's cross" superimposed, forming thus eight arms. This is the last sign or symbol on the almanack. I have gone through them all; but counting the days to the end of this quarter I find three too many, that is five altogether. These are evidently some of the original markings; but the outside edge at one end bears, besides these, forty-three additional notches. These seem to be much more recent than the others, and to have been made by a different hand, and are neither as deep nor so carefully cut as they. I imagine that some individual found the stick (perhaps a century or two ago), and, supposing it to be an ornament for wall-decoration, thought he would complete the carving left unfinished by the former whittler, and so continued the notches along the edge. The date "31st July, 1778," and some letters, of which part of an "H" and "en" are plainly seen, were scratched, as with a needle, on one end. But this, I should say, is of comparatively recent execution.

Now with regard to the manner of using this almanack. Every ordinary year ends on the same day of the week which commenced it, and so the next year must begin with the following day (or, after Leap Year, with the second day following); and it would seem that it was a matter of memory with the owners to move back one or more days of the week—the long notches being sufficient to remind them that every seventh day must be set apart for worship. For instance, this clogg begins with a Sunday notch—a long one. Next year this must mark Monday; so the user would merely have to remember during that year that each notch really signifies the next day of the week; or, in other words, the series of names of the seven days, fifty-two times repeated, is moved back one notch. And so, for Leap Year, two notches. Thus the notches represent the days of the *year*, one in every seven being devoted to divine worship, to intimate which it is marked with a longer notch. So it is not strictly correct, however convenient, to speak of the long marks as "Sunday notches."

Speaking of the symbols on the very complete "Staffordshire clogg," Dr. Plot says they "all carry with them a rational impor-

tance, some of them pointing out the offices or endowments of the Saints; others their martyrdoms; and others some eminent action or other matter some way relating to the Saint; or else the work or sport in fashion about the time when the feast is kept."

From this extract, and the above description of the clogg in the Museum, it will be seen that, owing to the frequent use of the cross and the fewness of symbols peculiar to certain saints, either (1) these signs were unknown to the maker, or that (2) he was too indolent to make them. But I think that the carved decoration at the commencement, the careful manner in which the original notches, crosses, and other signs are cut, would completely overthrow the latter assumption.

Thus it would seem that it was made very many years ago; or, at all events, if so lately as the 17th century, in some remote district which had but little communication with any centre of information.

Some of the symbols are similar to the Gothic Characters (Dominical Letters) engraved upon the Danish rimstocks and Norwegian primstaves (*vide* Plot's *Nat. Hist. Staf*, folio, 1686, p. 421, &c.), but do not seem to occur with any regularity.

Vide also Stephen's *Old Northern Runic Monuments of Scandinavia and England.* London and Copenhagen, 1866–7. Vol. II.

XII.—NOTES ON SOME RECENT DISCOVERIES OF INTEREST IN THE GEOLOGY OF THE PUNJAB SALT RANGE. By A. B. WYNNE, F.G.S., F.R.G.S.I.

[Read, February 17, 1886.]

Having written several Reports and Papers upon the Geology of the Salt Range, I may be excused from any lengthened discussion of the subject now; but it is necessary here—at the distance of some 5000 to 6000 miles from that region—to allude briefly to the position of the Range, and to some of its general features in order that the points I have to notice may be better understood.

Geographically, the Salt Range is somewhat peculiarly situated, subtending an angle formed by the meeting of two great mountain systems, the Himalaya on one side, and the Suliman Range, associated with the mountains of Afghanistan and Beluchistan, upon the other.

From the thrust, apparently, communicated by these ponderous mountain masses the Salt Range seems to have been distorted along its general line of direction, as if forced to adapt itself to narrower limits than its full extent would occupy. It presents a grand facade of bold escarpments towards the plains and desert to the south, rising above these generally some 2000 feet, with a culminating elevation at Sakésir Peak of more than 5000 feet. From a northerly aspect, the whole range and its plateaux form, relatively speaking, a much less lofty feature, bordering the steppe-like upland, undulating country, called the Potwar, or Rawul Pindi District, which rises say 1600 to 1700 feet above the sea.

Eliminating the numerous fractured or more complete curvatures of its strata, the Salt Range may be regarded as presenting, otherwise, a generally uniclinal or semi-anticlinal structure, the outcrops in most cases being presented to the south, and the whole series of which it is formed taking ground so as to pass beneath the Potwar, northwards.

Amongst its many interesting features, it may be noticed that the Salt Range is both geologically and economically

important—geologically, because it is one of the only instances within the great realm of India affording the opportunity of studying the structure of more, very much more, than the mere surface deposits overspreading the border lands which intervene between the almost totally distinct areas of the ancient peninsular Indian formations, and the, geologically speaking, as a rule, more modern systems, of which the Himalayan and Suliman mountains are composed. In these two great regions, even though certain contemporaneous formations may exist, the representative groups belonging to each are found to possess most marked dissimilarity of character.

Economically, the Salt Range is important by reason of the inexhaustible mineral wealth represented in its enormous deposits of rock-salt. Extending through a distance of 130 miles, with a known thickness in parts of 550 feet, these deposits have demanded the construction of a special railway, and the bridging of a great river, the Jhelum (or Hydaspes of the Ancients), to facilitate the transport of the salt, while the latest information at my command showed the (then increasing) annual salt revenue, to equal £382,653 sterling, although but a few of the mines known were being worked by Government, and the railway I have alluded to was not in existence.

One strikingly-pronounced peculiarity of the geological sections displayed by the whole range is, that the series, as found in the centre and at either end, differ all three as to their comprehensiveness; groups present in the east die out to the west, while others come into those sections, notably the Carboniferous and Ceratite-beds, and at times some portions, like the typical Olive-beds, disappear both to the east and to the westward. The whole arrangement, though accompanied by some considerable evidence of overlap, shows a continuous tranquillity of deposition and succession, without intervening violent disturbance of any kind, between two constant horizons, that of the salt marl below, and that of the Tertiary formation at the top of the series—that is to say, from a period not newer than Silurian (according to competent Palæontologists) through all the æons of Palæozoic, Mesozoic, and Kainozoic time, up to the date of the Miocene or later disturbances to which the Salt Range, as well as the Himalaya and Suliman mountains, mainly owe their origin.

One may well pause before accepting as real this apparent tranquillity of succession throughout so vast a range of geological chronology, but nevertheless the signs of a contrary state of things, so far as the Salt Range is itself concerned (and despite it being now an active earthquake region), if present at all, are so slight and so obscure as to evade the recognition of all but the most visionary of observers.

With regard to the Salt Range series generally, after mature deliberation on the evidence as it stood, and after frequently expressed concurrence, from its palæontological aspect, on the part of Dr. Waagen when in consultation, it has been found to contain groups or divisions reckoned from above downwards, synchronous with the five newest principal divisions of the general geological scale. The Lias was not recognized, but the presence of a Permian horizon, at first included in our Carboniferous group, was subsequently recorded by Dr. Waagen (*Pal. Ind.*, ser. XIII., Productus Limestone Group, 1879, etc.).[1]

This carboniferous or Productus Limestone, &c., is largely developed in westerly localities. Beneath it there are two azoic, or as yet unfossiliferous groups of uncertain age, but below them comes the Silurian or *Obolus* zone, the age of which was long since determined by the late Drs. Oldham and Stoliezka from the *Obolus* or *Siphonotreta* which I had found in it.[2] This zone rests upon a thick mass of purple sandstones (dying out to the west), which overlies the lowest and oldest group of all, the bright-scarlet

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[1] In this publication, since our joint determinations were reached, Dr. Waagen has in several cases cast doubts upon these results, always avoiding any allusion to his own share therein. In his most recent Paper, *Records Geol. Sur. Ind.*, vol. xix. pt. 1, 1886, p. 22, received since most of the present communication was written, the same habit still seems to cling to him, as where, at p. 33, he relegates the Salt-pseudomorph zone, for which a Triassic age was indicated, at his own suggestion, to the Palæozoic period as not greatly different from older Carboniferous.

This "Carboniferous group," as originally undivided, is remarkable for having afforded the earliest known *Ammonite*, and the very peculiar Brachiopoda, Lyttonia and Oldhamina (Waagen), these or allied forms being only found in two or three other distant eastern localities—one in China, another in the Ural, and again in the Alpine Rhætic. The *Oldhamina* had previously been described, apparently from a single specimen, as a *Bellerophon* by de Koninck, whilst the interiorly-ribbed valves of *Lyttonia* had been mistaken for fish-teeth. Specimens of the fossils were laid before the meeting, and afterwards presented to the Museum, Trinity College, Dublin. (See *Pal. Ind.* ser. xiii., Salt Range Fossils I., Productus Limestone Fossils IV. (fas. 2), 391 *et seq.*)

[2] See my Report on Salt Range, Mem. G. S. Ind., vol. xiv. pp. 95, 221.

and crimson, gypseous, Salt-bearing marl. In their regular natural order, the newest uppermost, these groups have been classified thus:—

Kainozoic	11. Siwalik and older, . .	Sandstones and clays.
	10. Eocene, Nummulitic, .	Chiefly limestone, with coaly beds at the very base.
Mesozoic	9. Cretaceous, ...	Olive and other sandstones, and boulder beds.
	8. Jurassic, ...	Variegated sandstones and shales.
	7. Triassic, ...	Red flags, greenish shales, &c.
Palæozoic	6. Carboniferous (and Permian of Waagen), . .	Limestones chiefly, containing the oldest known *Ammonite*.
	5. Speckled Sandstones, .	Sandstones, shales, clays.
	4. Magnesian Sandstone, .	Pale or whitish sandstones.
	3. Silurian, ...	Dark, clunchy, sandy shale.
	2. Purple Sandstone, . .	Sandstone, carthy below.
	1. Salt Marl, ...	Red gypseous marl and salt.

Premising that this list is compounded from various sections of the whole range, it will be observed that it includes no established representative of the Devonian or Old Red Sandstone period.

Having thus briefly acquainted ourselves with some general features of the range, we may turn attention to the recent very interesting discovery of several determinable fossils by H. K. Warth, Ph.D., in a thin layer of conglomerate occupying a position near the top of the boulder-beds in the lower part of group No. 9 of the foregoing list, and of others at the base of the overlying group No. 10.

The locality which has furnished the fossils is in the eastern part of the range, about a place called Pid, at some distance north and north-west from the principal salt mines, named the Mayo Mines (after our distinguished fellow-countryman, Lord Mayo, whose brilliant career as Viceroy of India was brought to a melancholy close by his assassination at the Andaman Islands).

Many years ago Dr. Oldham found fossils just beneath the

coal crops at the base of the Nummulitic limestone hereabouts, but the credit of this discovery of the organic remains, at the lower level just above the local boulder-beds, belongs entirely to Dr. Warth, who has lived ere this, for years, in the salt range, as superintendent of the salt mines and Salt Revenue Collector, and who has lately been employed there by Government under the Board of Works, to conduct explorations and boring operations along the irregular, but laterally extensive, coal deposits. Being familiar with the local geology, notices of which have largely entered into his reports on the mineral ground; my friend Dr. Warth was most competent to search the country in even greater detail than my own opportunities afforded means of doing, at any one particular place; and in this instance he has been most successful.

The sections of the range in and about this region exhibit the following succession of beds:—

11. Tertiary sandstone.
10. Nummulitic limestone, with the coal beds[1] in a shaly zone at its base.
9. { *a.* Pale or light-coloured, and reddish sandstone.
   b. Dark shales and olive sandstones with boulder-beds constituting the "Olive series" or group.

These boulder-beds of g. b. resemble those of the Talchir group of Central India, according to the descriptions given and also verbal communication from Mr. W. Theobald. (I have not seen the Talchir boulder-beds myself.) They occur generally in the lower part of the Olive group, and they include a variety of rounded and sometimes glaciated metamorphic rocks, the glaciation of which was first noticed by Mr. Theobald.

7. Red flags usually covered by a mass of red clays, the flaggy beds, characterised by their surfaces being often thickly covered with pseudo-morphic casts of cubical salt crystals. The beds have been doubtfully considered Triassic in my report, at the suggestion of Dr. Waagen.
4. Pale magnesian, and silicious sandstone, and some shales—beds often ripple-marked, generally quite unfossiliferous or obscurely fucoidal.

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[1] Specimen exhibited of a superior sample.

3. *Obolus* band—dark, clunchy, micaceous shales, with small *Obolus* or *Siphonotreta.*
2. Purple sandstones of several hundred feet thickness.
1. Salt marl, with salt beds and much gypsum.

Except the groups Nos. 3, 10, and 11, of this list, most of the series has proved hitherto unfossiliferous, but in disturbed portions of the group No. 9, presumed to be Cretaceous, I found a few lanceolate leaves and obscure shells, and in No. 4, some sharks' and other teeth. It is in the upper portion of the (presumed) Cretaceous zone, with its glaciated boulders, and also in the basal portion of the almost immediately succeeding early Eocene or perhaps partly Cretaceous group, that Dr. Warth's recent discoveries of fossils have been made. He writes that at, and below, the outcrop of the coal he found more than one carapace of fossil turtles three-feet in length, accompanied by *Belemnites*, and fish teeth, all in the same band, probably latest Cretaceous or of earliest Eocene age. He has sent me none of the Chelonian remains, but specimens of the *Belemnites* and fish teeth, include, according to his own label-tickets, *Lamna* sp., *Otodus* sp., *Hemipristis* sp., and *Capidotus* sp. At a lower horizon, but near the last, he found, in the Olive series, a thin band of conglomerate absolutely continuous for several miles, many of the pebbles in which enclose small *Conularia*,[1] and a few other shells. They occur also in the matrix in a rolled state, for one specimen, to which Dr. Warth calls special attention, is palpably an abraded, rolled *Conularia*, itself a pebble of the bed, taken from the matrix in this state—according to its label.[2]

[1] Specimens exhibited, and presented with the others to Museum, T. C. D.

[2] Dr. Waagen in his Paper ("Note on some Palæzoic Fossils, recently collected by Dr. H. Warth in the Olive group of the Salt Range."—*Records G. S. Ind.*, xix. p. 22, just to hand) does not agree in this statement of the case. He asserts the pebbles to be concretions and the beds to contain the fossils *in situ*. I have other evidence that he spoke of these pebbles as concretions in October, 1885. His Paper had not reached me when I wrote the passage describing the mode of occurrence of the fossils, and my statement was made, both on the authority of Dr. Warth, who is perfectly competent to distinguish pebbles from concretions, whether in, or away from, the bed that had enclosed them; and also from several examinations of specimens of these pebbles which I had received from Dr. Warth. They are of fine, grayish or brownish non-calcareous sandstone, of even homogeneous texture, well-rounded and worn, the surfaces cutting across the enclosed fossils, and they present no trace of any internal concretionary structure. Even if they have once been possibly nodules, they now bear the entire aspect of worn transported pebbles.

The genus *Conularia* (according to Nicholson) ranges from Older Palæozoic up to Liassic, but those found by Dr. Warth have been at various dates attributed by Dr. Waagen to different Palæozoic periods. In March, 1885, he considered them probably Silurian;[1] in October he called them Devonian,[2] and early in the present year (1886) he most strongly asserts them to be of Carboniferous age.[3] The several fossils of this thin conglomerate layer, as found by Dr. Warth, have been determined by Dr. Waagen as follows:—*Conularia lævigata*, Morris; *Conularia tenuistriata*, M'Coy; *Conularia*, cf. *irregularis*, Kon.; *Bucania*, cf. *Kuttaensis*, Waagen; *Nucula*, sp. indet.; *Atamodesma* (?) *warthi*, Waagen, n. sp.; *Aviculopecten*, cf. *limæformis*, Morris; *Discina*, sp. indet.; *Serpulites warthi*, Waagen, n. sp.; *Serpulites tuba*, Waagen, n. sp. All of these except the *Bucania* are figured in Dr. Waagen's plate, accompanying his Paper.[4]

The question remains, whence came these fossiliferous pebbles which do not seem to have been transported for any very great distance? Their material recalls nothing with which I could absolutely identify them from memory in the older groups of the Salt Range, their pale colour only—if even this is an original characteristic—might be more suggestive of their connexion with the Magnesian Sandstone (in which I could, however, detect no fossils)

Writing about them, from their very locality, Pid, under date December, 1885, Dr. Warth says, "From Choah-Saidun-Shah to Mackrach, I have found the thin conglomerate bank with the pebbles which enclose *Conulariæ*, and two or three other shells, absolutely uninterrupted in the 'Olive series' (upper portion). I send you a single *Conularia* (No. 16) which was found in a rounded-off state in the conglomerate. It is evident that the *Conularia* have not become fossils on the spot, but have been brought from a distant mountain as pebbles." The label of this specimen, No. 16, states, in Dr. Warth's writing, that he took it "in its present state from the face of the bed."

No person who inspects this rolled specimen can for a moment doubt the accuracy of Dr. Warth's description or the derived character of itself and the other fossiliferous pebbles. Dr. Waagen's account of them, for which indeed he advances no valid reasons, must therefore be received with caution or rejected, and with it almost the whole of his speculative deductions regarding the pebbles themselves, the layer which contains them, the "glacial boulder beds" of the Range, and his elaborate Palæontological views of the palæozoic and mesozoic geology of the eastern hemisphere and other regions.

[1] *Records Geol. Soc. Ind.*, vol. xix. pt. i. p. 1.

[2] MS. Correspondence, London, October 9, 1885.

[3] *Records* cit., vol. xix. p. 29.

[4] *Records* cit., p. 25, etc., which reached me only in time to add the list of species given in the Press.

than any other of these older sub-divisions, but there is still the difficulty that a fossiliferous conglomerate band, having an extent of several miles, would indicate the existence of the parent beds within measurable distance, while none of the layers of the Magnesian Sandstone group have given encouragement hitherto towards a hope that fossils would ultimately be found in them.

If we turn, unwillingly, from the possibility that the fossils were derived from this source, and look for another outside the Range itself, I know of no rocks in the outer Himalayan region to the northwards and north-east, more likely to have furnished the pebbles, and to the southward the flat alluvial plains and desert stretching away towards Sind are unbroken except by a small group of hills on the Chenab River, called the Korana Hills, separated by some forty miles from the Salt Range. I have seen these only from the range itself, but Dr. Fleming has described their rocks in a Paper to the Asiatic Society of Bengal (vol. xxii., new series, 1853), as dark, "coarse-brown ferruginous quartzose sandstone, alternating with beds of a greenish quartzite, which in many places passes into silicious clayslate," the sandstone being traversed by numerous quartz veins containing masses of hematite.

Another observer, my former colleague, Mr. Theobald (*Jl. As. Soc., Bengal*, vol. xxiii. p. 674), describes the rocks of these hills as deeply ripple-marked slate—the slaty structure feebly developed, gray in colour, stained red and yellowish, weathering to a deep-burnished brown, &c. The whole of these characters stamp the rocks as widely different from any of the Salt Range groups: this of itself may favour the supposition that they formed the basal portion of a series, some part of which may have existed as the land from whence the Conularia-pebbles were derived.

I have elsewhere mentioned the occurrence at more than one widely separated Salt Range horizon[1] of conglomeratic zones

[1] My view as to the difference of horizons at which these boulder-beds occur is not accepted in Dr. Waagen's recent Paper in the Indian Records previously referred to. He regards the whole of these boulder-beds as glacial, and as occurring upon one horizon (p. 34). Stratigraphic conclusions are only geologically valuable when based upon carefully observed and compared facts and observations. My conclusions are the results of such examinations, and Dr. Waagen has advanced nothing which leads me to abandon them, while, I regret to say, the more I consider the matter the less reason I see far adopting his views to the contrary, these being directly at variance with stratigraphical facts.

having usually a soft matrix and intensely hard metamorphic pebbles and boulders. They are found just at the upper surface of the salt marl in the west part of the range, and at one or two other stages before being again largly developed in the lower part of the Olive group, which contains the Conularia-layer, apparently at a slightly higher horizon. There is no known source for any of the various metaphoric rocks to be found in these boulder-beds, including a red granite which would be easily recognized either among the Himalayan or Afghan mountains, if it existed in any force, so that here again an old metamorphic region, lying to the southward, suggests itself as forming land at various periods during the long record of the Salt Range rocks. Whether this may have formed, or not, a portion of the lost continent, Lemuria, supposed to have at one time united Africa with India, it is not for me to say; but failing the future discovery of similar forms or others of similar age in the hitherto azoic beds of the older portion of the Salt Range series, I am disposed to think these pebbles must have come from lands and rocks long since buried beneath the country southwards of the Salt Range, now occupied by the arid plains and deserts which lie in this direction.

XIII.—ON THE DIFFERENT VARIETIES OF IRISH PAVING-SETTS. By PROFESSOR EDWARD HULL, LL.D., F.R.S., Director of the Geological Survey of Ireland.

[Read, February 17, 1886.]

The Royal Dublin Society seems the most suitable place for the discussion of all questions connected with the industrial products of Ireland, amongst which may be reckoned paving-stones.

The production of paving-stones (or paving-setts, as they are generally called) is comparatively recent in Ireland, as this country has for a long time been dependent on imported stone, particularly from North Wales, notwithstanding that there are equally good sources of supply in various parts of Ireland itself. The discredit of depending on a foreign supply for a material which is abundant at home is happily being removed; and it is not improbable that, ere long, the course of this trade will be reversed; and that, instead of being a large importer, Ireland will become a large exporter of this useful commodity; in fact, I may say that the current has already changed.

In considering the question of the utilization of paving-setts, we have first to consider their *qualities;* next, the varieties of mineral composition and mode of formation; and, lastly, the sources of supply; which, as far as this Paper is concerned, will be specially restricted to those now existing in Ireland.

I. *Qualities requisite for Paving-setts.*—The qualities requisite for paving-setts may be described under three heads:—

(*a*) Uniformity of texture and composition, which we may call "homogeneousness";

(*b*) Toughness; and

(*c*) Roughness of surface.

A few observations may be made upon each of these heads:—

(*a*) *Uniformity of Texture and Composition.*—This is an essential quality in paving-setts, as it will be evident, on reflection,

that should the stone be wanting in homogeneousness it would be liable to break down under traffic, the softer portions giving way before the harder, and thus causing the blocks to collapse. It will be found that all the rocks used for the production of setts possess this quality, though differing from each other in other respects.

(*b*) *Toughness.*—I prefer the term to *hardness*, inasmuch as many very hard rocks—such as flint, chert, and quartzite, are deficient in toughness; and are, consequently, liable to crack, and splinter upon percussion. Such rocks are therefore unfitted as materials for paving-setts, which ought to be capable of withstanding the percussion caused by the sudden shock of the wheels of heavily-laden vehicles passing over their surfaces, not to speak of those caused by the iron-shod feet of dray-horses.

(*c*) *Roughness of Surface.*—This is a quality not less valuable than that of toughness, and the best varieties of paving-setts are those which combine these three qualifications. It has been found by experience that some of the harder kind of paving-setts are liable, after some wear and tear, to have the surfaces worn smooth, and actually to become polished. In this state they become dangerous for street traffic; and, notwithstanding their durability, they are held in less favour in the large manufacturing towns of the North of England than was formerly the case; and other kinds of stone, though somewhat softer and less durable, are preferred, in consequence of their ability to maintain a rough surface.

II. *Varieties of Stones for Paving-setts.*—I now pass on to consider briefly the varieties of stone suitable for the manufacture of paving-setts, and therefore combining in a greater or less degree the qualities previously enumerated. They may be considered under three heads:—

(*a*) Those of sedimentary origin, such as grits and sandstones.

(*b*) Those of igneous origin, of a granitoid character; including quartz-porphyries.

(*c*) Those also of igneous origin, but belonging to the variety commonly known as "whinstone"; including basalt, dolerite, diorite, and felstone.

(*a*) *Grits and Sandstones.*—The formation which yields this class of paving-setts in greatest quantity is the carboniferous; and beds belonging to the millstone grit division in Lancashire and Yorkshire are largely worked for paving-setts. This rock, owing to its granular structure, is probably the softest of all the varieties of stone capable of being used for paving purposes; still, it is very largely used in the streets and roads of the North of England for pavements; and is found, when properly selected, to answer well where the traffic is not excessively heavy. Gritstones have the useful quality of preserving a rough surface; and can be set quite close, side by side. As far as I am aware, there are no paving-setts made from the carboniferous rocks of Ireland, though I have no doubt some of the beds of grit of this formation in the counties of Sligo, Fermanagh, Leitrim, Donegal, &c., are capable of producing them. In Belgium the gritstones of the Upper Devonian formation, known as the "Psammite du Condroz," are very largely used for paving the streets of the manufacturing and other towns.

(*b*) *Granitoid Varieties.*—This group includes not only granites, but quartz-felstones and porphyries; in which the constituents are quartz, felspar, with mica or hornblende as accessories. These components are, more or less, in a crystalline condition, and have solidified from a state of igneous fusion. In consequence of this, the mineral constituents are firmly bound one to the other, and a condition of "toughness" is imparted to the mass favourable to its use for paving-stones. The presence of mica, if in large flakes, would prove a source of weakness, in consequence of its want of cohesion with the other minerals; but when in minute flakes, this mineral, by its disintegration, enables the stone to preserve a constantly rough surface.

Paving-setts belonging to this group are worked at Bessbrook, Goragh Wood, and Castlewellan, in Ireland; and at Mount Sorrell, in Leicestershire.

(*c*) *Whinstones.*—The stones belonging to this third division differ from those already described in texture and composition. They consist of crystalline aggregates of felspar and augite, or felspar and hornblende, together with magnetic iron-ore disseminated in minute grains, and with occasionally other minerals, such as olivine, and chlorite, in small quantities. The presence of

iron gives to these rocks a higher specific gravity than those of the granitoid class, in which iron is either absent or occurs in exceedingly small proportions. Thus, while the average specific gravity of granitoid rocks may be taken at 2·65, that of the whinstones may be taken at 3·0; so that, in the case of a contract for purchase by weight, the granitoid rocks are in favour of the purchaser.

The rocks of the "whinstone" class are generally exceedingly tough, and setts taken from them are capable of withstanding the heaviest traffic; but their chief defect is the tendency to wear into smooth surfaces and become slippery. Being essentially compact in structure, the component minerals are incapable of individually disintegrating, and thus preserving a rough exterior where subjected to wear and tear. This is the case, at least, with regard to the finer and denser varieties; and it is therefore important, in selecting a stone of this class for paving purposes, to see that it is largely crystalline-granular, as such varieties will be less liable to wear smooth.

Quarries for making paving-setts from whinstone have been for some time past opened at Ballintoy, Co. Antrim, and Arklow, Co. Wicklow. The Welsh setts from the quarries at Penmaen Mawr belong to this group, and have been largely used not only in England but in Ireland, where stone of similar or identical qualities is to be found in abundance. The great obstacle to the manufacture of paving-stones in this country has been—not so much want of capital or enterprise on the part of the employers of labour—as want of knowledge in the art of shaping the stones on the part of workmen. This want is now being supplied, as Irish stonemasons are being instructed by workmen from Wales and England; and as we possess abundance of the raw material, we may look forward with hope to a large and flourishing trade in various parts of the country.

In considering the qualities of different varieties of paving-setts, and the purposes to which they should be applied, I think we may fairly come to the conclusion:—that for streets subject to excessively heavy traffic, the whinstone varieties, especially those of largely-crystalline structure, are the more suitable; while for streets with ordinary traffic, those of the granitoid class will be found sufficiently durable, and, from wearing rough, more advantageous.

Irish Localities for Paving-setts.—Having personally visited most of the quarries from which paving-setts are now being obtained, I will, in conclusion, give a short account of each, commencing at the north coast of Co. Antrim.

Ballintoy Quarry.—This quarry is worked by the Eglinton Chemical Co., Limited. The rock consists of a largely-crystalline dolerite, forming a cliff 80 feet in height, in rude columns, and about 200 yards in length. The stone is shipped at the little harbour of Ballintoy and sent to Glasgow, Londonderry and other places. It consists of a crystalline aggregate of augite, plagioclase, olivine, and magnetite. I understand that paving-setts could be delivered in Dublin, at 22*s.* per ton.

Goragh Wood.—This quarry belongs to Messrs. J. Robinson and Son, of Belfast, and is opened by the side of the Great Northern Railway at the junction for Newry and Armagh. The rock consists of fine-grained granite of quartz, felspar, and black mica in small flakes. The paving-setts are sent to Belfast and other parts of Co. Antrim, and have likewise been used in Manchester, Oldham, Liverpool, Rochdale, and other towns in England; and the stone for building and decorative purposes, takes a fine polish. It can be delivered in Dublin at prices varying from 18*s.* 6*d.* to 21*s.* per ton, according to the size of the "cubes."

The Castlewellan granite is considered more suitable than the Goragh Wood stone for paving, being somewhat harder; and is being used by the Belfast Harbour Commissioners for paving the street along the Donegall-quay, where the traffic is naturally heavy. For building purposes the stone was selected, amongst other places, for the Bishop Rock Lighthouse at St. Mary's Island, Scilly. Paving-setts of this stone can be delivered in Dublin at prices varying from 19*s.* 6*d.* to 22*s.* per ton, according to the size of the "cubes."

Bessbrook, near Newry.—These quarries, which belong to the Bessbrook Granite Co., Limited, are opened in granite, consisting of quartz, felspar, and black mica in small flakes. The rock is extensively worked both for setts and also for building and ornamental purposes, and the stone is shipped at Newry, or sent by rail. I understand the company have offered to supply paving-setts to Dublin at 22*s.* 6*d.* per ton, though the regular price is 24*s.* The stone is used in various parts of England, including Manchester,

Chester, and Wigan, and for several of the approaches to railway stations where there is heavy traffic.

Arklow, Co. Wicklow.—These quarries, which belong to Mr. Parnell, M.P., produce three separate varieties of stone. From the samples I have received they may be described as belonging to the whinstone class.

No. I. is a coarse-grained crystalline diorite, or greenstone, of a dark-green colour, consisting of felspar, hornblende, and some magnetite. It occurs in the form of a dyke penetrating the Silurian slate along the banks of the Aughrim river, about a mile above Wooden Bridge Inn. The rock breaks with a rough surface, and shapes well into setts.

No. II. is a coarsely-crystalline felstone of a dark-blue colour, with a little pyrites in distinct crystals. It breaks with a rough surface, and is lighter than No. I.

No. III. may be described as a compact felstone of a bluish colour, with even fracture. Setts from this rock would be liable to wear with a smooth surface, on which account it is, in my opinion, inferior to Nos. I. and II.

The stones from the Arklow district are now being largely used in the city of Dublin; and I understand from Mr. Parke Neville, the Borough Engineer, that the price paid under last contract was 24*s*. per ton delivered at Harcourt-street Station or on the Quays.

In offering these few remarks on the nature and sources of Irish paving-stones, I have no intention of personally recommending any special stone to public favour; but only of affording data on which selections may be made for special purposes and localities. It will be gathered from what I have stated that, in my opinion, different varieties of stone have their own special uses; and that, in providing for the requirements of a large city, certain varieties may be more usefully employed in one part than another, according to the nature and amount of the traffic.

XIV.—NOTES ON TWO IRISH SPECIMENS OF EDWARDSIA TIMIDA (QUATREFAGES). By G. Y. DIXON, M.A. (With Plate VI.)

[Read, January 20, 1886.]

Edwardsia timida (Quatrefages).

Historical.

Edwardsia timida, . .	Quatrefages, 1842, *Ann. des Sci. Nat.*, Ser. 2, xviii., p. 70, pl. 2, fig. 1.
Edwardsia harassi, . .	Quatrefages, 1842, *ibid.*, p. 71, pl. 2, fig. 2.
Edwardsiella harassi, .	Andres, 1884, *Die Actinien*, Fauna u. Flora, d. Golfes, v. Neapel, ix. p. 94.
Edwardsiella timida, .	Andres, 1884, *ibid.*, p. 96.

This species has previously been recorded from only one district—Chansey, Manche (North France), where it was found by Quatrefages. Last autumn, however, I had the good fortune to find two specimens at Malahide, county Dublin. With the exception of an immature Edwardsia found by Professor A. C. Haddon at Salthill, Dublin Bay,[1] this is, I believe, the first example of this genus recorded from Ireland. Quatrefages separated *E. timida* from *E. harassi* on four grounds:—(1) the tentacles in *E. timida*, he thought, were in a single row, while those of *E. harassi* were arranged in two rows. I believe this distinction is only due to the different state of extension of the disk. For when the animal is much extended the tentacles appear to be uniserial; but when it is not extended to its full size they seem to be in two distinct rows, alternately arranged. (2) Quatrefages describes the mouth and disk of *E. timida* as flat, and those of *E. harassi* as being raised so as to form a terminal papilla. This distinction also I believe to be based on a merely temporary condition : in both my specimens the mouth and disk were continu-

[1] *Proc. Roy. Ir. Acad.*, 2nd ser., vol. iv., p. 527.

ally undergoing changes of form, being sometimes flat, sometimes raised into a pointed cone, with the lips protruded and folded back. (3) Quatrefages makes the consistence of the investment a further ground of distinction. Andres, however (*l. c.*, p. 93), refuses to give any weight to such a matter as this, as a specific distinction among the Edwardsidae, considering that the nature of the investment largely depends on the environment of each individual. In connexion with this question, too, it should be borne in mind that Quatrefages found the one example on which he rests his *E. harassi* in a different locality from where he found the specimens which he referred to *E. timida.* (4) Lastly, *E. timida* measures 6–7 cm. in length, while *E. harassi* only measures 5½ cm. This would not appear to me to be an important difference, but merely to depend on the temporary elongation or contraction of the animal.

Quatrefages referred all Edwardsidae to one genus, Edwardsia. Andres has constituted two genera in the sub-family, reserving the name Edwardsia for all such species as have sixteen tentacles, and classing under the name Edwardsiella all those that have twenty or more tentacles, including, of course, the *E. timida* and *E. harassi* of Quatrefages. In the present state of our knowledge no advantage would seem to follow from multiplying the genera, and therefore I have adhered to the nomenclauture of Quatrefages. My two specimens evidently belong to the same species, but as they differ somewhat from one another, I have described both. All the features in the following description are common to both specimens, except where a separate description is given of each under the several designations of α and β.

DESCRIPTION.

Form.—Column thin, very much elongated ; divided into physa, scapus, and capitulum.

Physa—delicate, smooth, retractile within the scapus ; when fully distended exceeding the scapus in diameter, and sometimes rising from it by an abrupt step ; studded with minute suckers ; divided into eight segments by eight lines, which correspond with the insertions of the mesenteries ; no terminal pore is present.

Scapus—long, slender, vermiform, slightly tapering towards either extremity, cylindrical, smooth, without tubercles or longitudinal ridges or furrows ; clothed with a transversely corrugated

investment, which is opaque, leathery, flexible, and rough; the investment breaks off abruptly at each of its extremities, and is more deeply furrowed and wrinkled, and studded with particles of sand at its anterior end. When the animal is much contracted eight longitudinal ridges sometimes rise at the anterior extremity, and extend for a very short way down the scapus: no other longitudinal marks are visible except when the animal is much distended, in which case the lines corresponding to the insertions of the mesenteries can be seen through the investment, especially in the region towards the physa. When the investment is removed the insertions of the mesenteries are seen in the body-wall as in *Peachia hastata.*

Capitulum—delicate, retractile within the scapus, columnar; its body-wall is divided perpendicularly into eight broad regions, separated by as many narrow flutings; the broad regions (which apparently correspond to Gosse's "invections"), being somewhat swollen.

Tentacles—marginal in two rows, the inner usually pointing upwards, the outer extending horizontally; obtuse, slender, hardly tapering towards the top.

aa—tentacles 22 in number, 8 being arranged in the inner row, one at each end and three at each side of the mouth. Each of the inner tentacles thus occupies the centre of one of the inter-mesenterial chambers. From between the mesenteries which run into either end of the mouth ("the directive mesenteries") there rises but one tentacle. At one end of the mouth each of the chambers adjoining that formed by the directive mesenteries have four tentacles—one in the inner and three in the outer row. Each of the remaining chambers gives rise to three tentacles—one in the inner and two in the outer row.

ββ—tentacles twenty in number, arranged ten in the inner and ten in the outer row.

Disk—usually elevated into a cone; each inter-mesenterial space being arched upwards between the mesenteries, and having a somewhat puffed and swollen appearance.

Mouth—prominent; linear; lips frequently protruded and folded back over the disk.

Colour.—*Physa*—pellucid white, marked with eight white longitudinal lines.

Scapus—(1) *Investment;* brownish-orange for two-thirds of its entire length; at the anterior end it grows darker, till it becomes almost black at the top.

(2) *Body-wall*—pellucid pale pinkish flesh-colour, showing the insertions of the septa as whitish longitudinal lines. When the scapus is much distended the orange convoluted edges of the mesenteries may be seen hanging free in the interior.

Capitulum—transparent brownish red, deeper above, paler below; each invection bears an arrow-head mark of pure opaque cream-white pointing upwards, and about one-third of the total length of the capitulum below the tentacles. Between these arrow-heads and the scapus, on either side of each invection, closely adjoining the arrow flutings, there is an opaque white linear spot, running parallel to the direction of the flutings. When the animal is viewed by direct light, the flutings and invections seem to be separated by lines of transparent white; but when the animal is seen by transmitted light these markings disappear, and the opaque marks mentioned above seem black. The red colour of the œsophagus may be seen through the body-wall of the capitulum. When the animal is contracting, rings of pale brownish-red appear to encircle the capitulum, and are especially conspicuous across the white arrow-heads. These rings are really wrinkles caused by the process of contraction. Their presence proves that the white marks are imbedded in the substance of the body-wall. Sometimes the white colouring on the disk shines through the tentacles so as to be quite visible at the margin, when the animal is seen from the side. This effect, at the first view, would almost lead one to suppose that the margin, or top of the capitulum, or the back of the tentacle foot, was marked with a white band; but this is not really so, the back of the tentacle foot and the margin being quite monochromatic.

Tentacles—brownish-red, transparent, apparently with a core of the same colour, only denser. No bands or markings are present, the colour being uniform throughout.

Disk a—cream-white, with the eight septa showing through as brownish-red lines; the gonidial and gonidular tentacles have a dense white blotch at their base, but no other mark. Each of the remaining six primary tentacles has a band of white which encloses the front, but does not extend round to the back of its foot. Below

this band there is a V-shaped brownish-red mark, the apex of which points towards the mouth; while on either side of the mouth are two slightly-curved short linear marks running towards the mouth. There are no markings on the disk which correspond with the secondary tentacles.

Disk β—translucent pale brownish-red, with no coloured markings corresponding to the mesenteries; the bright-red œsophagus shining distinctly through in the centre; the mouth encircled with an opaque white band, which was shaded off gradually into the brownish-red which forms the general colour of the disk. Each tentacle is marked at the foot with a crescent of opaque white: these crescents, though they come very close to each, do not coalesce, but are separated by a thin streak of the brownish-red which is prolonged between them. Each crescent is shaded off into the general colour of the disk on the side towards the mouth, while the side next the tentacle is sharply and definitely drawn.

Mouth α—with brownish-red lips; on the inner edge of the lips are six pairs of small white spots, which correspond with the six lateral primary tentacles.

Mouth β—with bright-red lips, quite plain, without marks or spots.

Dimensions.—

Length—contracted,	35–40	mm.
„ expanded,	65–70	„
Expanse of disk and tentacles,	8	mm.
Diameter of scapus, greatest,	5	„
„ „ least,	2	„

Locality.—Malahide, county Dublin, south bank of the estuary, opposite the Hotel; in mud, among stones, at extreme low water.

I cannot conclude this description without stating that I am well aware of the difficulty raised by the account given of the arrangement of the tentacles in example β. However, I can only say that, after repeated observations made during the three months the animal was alive—observations always made, I may add, almost in the hopes of ascertaining the contrary to be the fact—I am quite certain that ten, and not eight, was the number of the tentacles in the inner row. In connexion with this point it is worthy of note, that Quatrefages, in his description of the disk of the very

species now under consideration, says, five lines of a violet black run from the circumference of the disk to the mouth, and that in the intervals between these lines five others of the same colour, only less marked, are to be seen. Agassiz, too, is evidently of opinion that there need not be an absolute conformity between the tentacles and mesenteries in Edwardsia. In describing the development of a larval Edwardsia (*Arachnactis*), he says: "Les nouveaux tentacules se forment independamment des cloisons ovariennes, et je n'ai pas pu en suivre l'indice exactement, relativement aux huit cloisons principales; mais comme je l'ai deja indiqué, les jeunes tentacules se forment toujours vers une des extremités—a l'extremité opposèe de la bouche ou se trove le long tentacule impair."—*Archiv. Zool.*, 1873, vol. XII., p. xxxviii.

HABITS.

The habits of my two specimens during the few months they lived in captivity were very much the same as those described by Quatrefages and by Andres in his description of a kindred species (Intorno all' *E. claparedii*, Mittheil. Zool. Stat. z. Neapel, 1881, II., p. 129).

I kept them in a small glass jar with about one-fourth inch of sand. They sometimes adhered to the sides of the glass vessel by the physa, sometimes burrowed in the sand, leaving only the capitulum protruded, and sometimes they wallowed about on the surface of the sand quite free: in the last-mentioned condition they were usually distended more fully than when fixed in the sand, or when adhering by the physa. Their shape and dimensions varied greatly according to the degree of their distension, but I think hardly to the extent observable in other free anemones, the presence of the investment seeming to limit them somewhat in this respect. There was generally a constriction marking the division of the scapus from the physa; and sometimes, when the animal was contracted, the capitulum was separated from the scapus in the same manner; but I never saw these constrictions passing up or down the body, as one sees in Halcampa or Peachia; on the contrary, they appeared to be fixed and constant in their position.

The physa was frequently covered with particles of sand, which seemed to be adhering in a thin coating of slime, for if the physa,

when in this state, was suddenly drawn up into the scapus, the particles of sand formed a ring round the posterior portion of the investment. When alarmed, it withdraws its disk and tentacles into the capitulum, and the capitulum itself into the investment, by a process of invagination. During the earlier stages of this process the white markings on the disk and on the capitulum may be detected through the body-wall, their position being inverted by the invagination.

NOTES ADDED IN PRESS.

Since the above Paper was written I have obtained six more specimens of *E. timida* at the same locality. In colour the new specimens differ considerably from each other, and from those already described. I have set out the points of difference of all the individuals I have seen in the accompanying Table.

The constant characteristics of the species seem to be—

1. The ratio of the length to the diameter, 1 to 18.
2. The pellucid pink colour of the capitulum, disk, and tentacles, varied with opaque white marks.
3. The absence of tubercles and longitudinal ridges.

EXPLANATION OF PLATE VI.

Edwardsia timida (Quatrefages).

Fig. 1. Side view of animal, natural size.
,, 2. Side view × 4 diam.
,, 3. Diagrammatic sketch of the disk of α × 8 diam.
,, 4. Disk of β × 8 diam.
,, 5. Capitulum closed × 6.

[*To face page* 106.

Specimen.	Numb of Tentacl	ɔur of Disk.	Colour of Investment.
α	22	ɔharacteristic marks in ve).	Tawny orange, black above.
β	20	, with white crescents of the tentacles, and a round the mouth.	Tawny orange, black above.
γ	20	pink: at the foot of le is a white mark like a very broad cross-bar: ɔsed in a white ring.	Pale drab throughout, with a black irregular stain on the scapus.
δ	18	k, with decided white und the feet of the ten- the mouth inclosed in a	Tawny orange, paler above.
ε	22	rose, with decided white nclosing the feet of the rom each of which two radial lines run towards which is inclosed by a	Tawny orange, black above.
ζ	21	llucid pink, with white ɔund the feet of the ten- the mouth inclosed by a	Tawny orange below, pale drab above.
η	22	, but speckled with very te spots; the feet of the nclosed in white cres- nouth inclosed in a white	Tawny orange, black above.
θ	24	ot observed.]	Tawny orange, black above.

Specimen.	Number of Tentacles.	Colour of Tentacles.	Colour of Capitulum.	Colour of Œsophagus.	Colour of Disk.	Colour of Investment.
α	22	Pellucid brownish-pink, not tipped with white.	Pellucid brownish-red, with decided arrow-heads and linear marks.	Brownish-red.	White, with characteristic marks in red (as above).	Tawny orange, black above.
β	20	Pellucid brownish-pink, not tipped with white.	Pellucid brownish-red, with decided arrow-heads and linear marks.	Brownish-red.	Pellucid pink, with white crescents at the feet of the tentacles, and a white ring round the mouth.	Tawny orange, black above.
γ	20	Pellucid pink; tipped with white, which is scarcely perceptible in full expansion.	Pale pellucid pink, with blunt arrow-heads, and no linear marks.	Brownish-red.	Pale pellucid pink: at the foot of each tentacle is a white mark like a H, with a very broad cross-bar: mouth inclosed in a white ring.	Pale drab throughout, with a black irregular stain on the scapus.
δ	18	Pellucid pink; tipped with cream-white, and marked with minute brackets)(on the back at the foot.	Pale pellucid pink, with irregular white marks instead of arrow-heads, and with very conspicuous linear marks.	Brick-red, with white longitudinal marks, which may be seen through the capitulum.	Pellucid pink, with decided white crescents round the feet of the tentacles, and the mouth inclosed in a white ring.	Tawny orange, paler above.
ε	22	Pale pellucid rose, tipped with white cream.	Pellucid pink, with arrow-heads and linear marks.	Brick-red, with white longitudinal marks, which may be seen through the capitulum.	Pale pellucid rose, with decided white crescents inclosing the feet of the tentacles, from each of which two short white radial lines run towards the mouth, which is inclosed by a white ring.	Tawny orange, black above.
ζ	21	Very pale pellucid pink, with conspicuous white tips.	Very pale pellucid pink, with slight and flattened arrow-heads, and no linear marks.	Yellow ochre.	Very pale pellucid pink, with white crescents round the feet of the tentacles, and the mouth inclosed by a white ring.	Tawny orange below, pale drab above.
η	22	Pellucid pink, with faint white tips.	Pellucid pink, with irregular marks instead of arrow-heads, and with the usual linear marks.	Brick-red.	Pellucid pink, but speckled with very minute white spots; the feet of the tentacles inclosed in white crescents, the mouth inclosed in a white ring.	Tawny orange, black above.
θ	24	Pale rose, not tipped with white.	Pellucid pink, with arrow-heads and linear marks.	Brick-red.	[Not observed.]	Tawny orange, black above.

XV.—NOTE ON SOME IMPROVEMENTS IN EQUATORIAL TELESCOPE MOUNTINGS. By HOWARD GRUBB, F.R.S.

[Read, January 20, 1886.]

New Declination Slow Motion.—The slow motion arrangements usually used in Equatorials are of either of two forms, viz.:—

(*a*) an endless screw working into a sector or portion of a toothed circle of long radius; or,

(*b*) A screw applying, or pushing directly against an arm, that arm being kept in contact with the screw by a spiral or some other form of spring having a considerable range of motion.

The first (*a*) possesses the disadvantage that, however carefully made, it is impossible it is quite free from "loss" or "back lash"; and, consequently, the position of the telescope is not perfectly determinate in declination, which fault is inconvenient when delicate measures are required.

The second (*b*) has practically no "back lash," as spring keeps the arm in perfect contact with screw, but it has the disadvantage, that whatever range of motion is required, the spring must be capable of working through the same range; consequently the spring will be much stronger in action at one end of the range than the other, unless it be made very long indeed, in which case its action is uncertain and unpleasant.

To remedy these defects the author has devised the following, which possesses the advantages of both:—

ABCD (fig. 1) is a portion of the arms attached to telescope, or cradle, on which is planted the block (*b*), forming the bearing of the screw. The nut (*n*) is in the form of a ball working in a socket on the extremity of the clamp-arm EFG. A short stiff spring (S) is attached to this clamp-arm, bearing, not directly against any part of other arm, but against end of a second screw of same pitch as the main screw, the nut of which (*oo*) is toothed on edge, and works into a wheel of equal size (*pp*) on main screw. The point of this second screw, therefore, advances as much in one direction as the frame ABCD is carried in other, according as the milled head

is turned; and, consequently, the point of the screw does not sensibly vary in its position with respect to the clamp-arm EFG. A

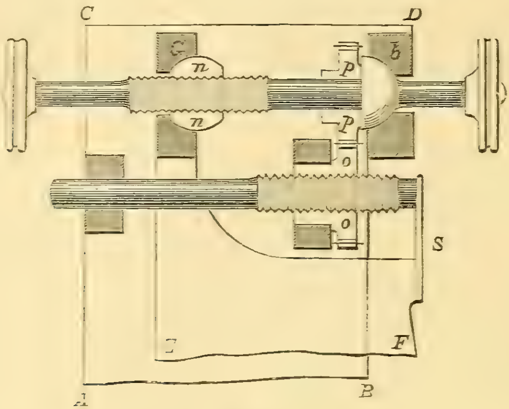

Fig. 1.

short stiff spring can therefore be used, and the disadvantage abovementioned disappears.

New Position Finder.—The inconvenience of having to rise from the observing-chair to read the Right Ascension and Declination circles of an Equatorial has tempted opticians to devise many contrivances by which the circles may be read from eye-end of tele-

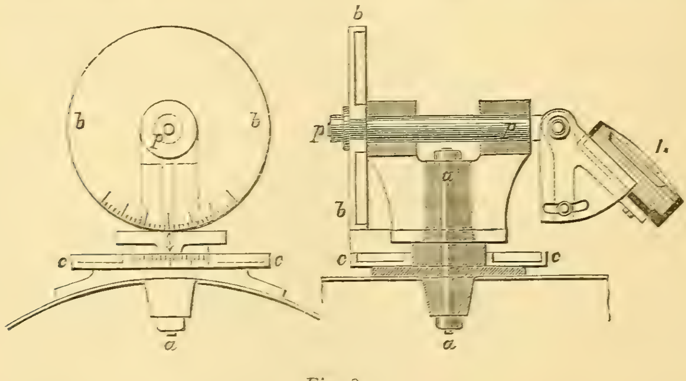

Fig. 2.

scope. In some cases the following piece of apparatus will probably be found useful. It can be attached at any convenient position near eye-end of telescope. It (fig. 2) consists of a circular level

mounted on two axes at right angles to one another, thus allowing of universal motion. The apparatus is so mounted on telescope that one of the axes (*aa*), which may be called its declination axis, is parallel to declination axis of telescope. If, now, telescope be pointed to equator, and meridian, and circle (*cc*) on declination of axis of position-finder made to read zero, the other axis (*pp*), which may be called its polar axis, will be parallel to polar axis of equatorial. The bubble of level L is now adjusted to centre when the circle (*bb*) on its polar axis reads zero.

It is evident now that the Right Ascension and Declination circles of position-finder will read the same as the Right Ascension and Declination circles of telescope, at any position provided the bubble be brought to centre of glass.

To find any object, it is only necessary to set the circles of this little position-finder to same readings as the Right Ascension and Declination circle of telescope itself would have to be set to, and turn instrument round till bubble becomes level.

Addition to Existing Arrangement for Slow Motion in Right Ascension.—The slow motion in Right Ascension

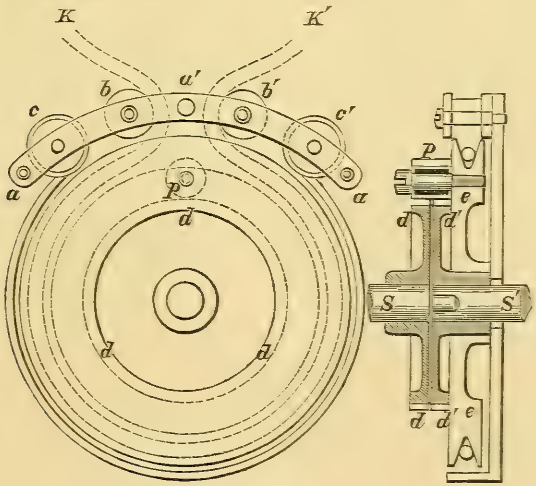

Fig. 3.

which the writer generally applies to his instruments has often been described. It consists (fig. 3) of a pair of differential wheels (*dd′*) fixed on the adjoining ends of a pair of shafts (*SS*) in line

with each other, into which wheels a pinion *p* is geared, this pinion being carried on a stud fixed to a disc (*e*) revolving free on shaft: when not in use the pinion acts as a clutch, and both wheels and shaft, pinion and disc, all revolve together by clock. When a fine motion is required in either direction, a cord passing over a groove in disc is pulled in one direction or other; the pinion revolves round differential wheels, and as the wheels have not exactly the same number of teeth, produces a differential motion which practically accelerates or retards clock-movement as long as cord is pulled, but the moment the cord is released all revolve together, as before, at normal rate.

The only objection that has ever been made to this motion is, that it requires two hands to work it—one to keep the cord a little "taut," and the other to pull, as otherwise the cord would slip round without gripping. There is more difficulty in overcoming this objection than may at first sight be apparent, for it will not answer to apply anything which will produce friction between cord and pulley, except at the moment the cord is pulled.

The following plan has, however, proved quite successful:—

A little frame (*aa*) is fixed over the pulley disc in such a manner that it is capable of a rocking motion in centre (*a′*). This frame carries four rollers (*b*, *b′*, *c*, *c′*). The pulleys (*b*, *b′*) are simple grooved rollers; (*c*, *c′*) are covered with india-rubber rings. When cord *k* is pulled, the whole frame slightly tilts, and brings the rubber-covered roller (*c′*) into good contact with cord on disc pulley, and prevents it slipping. When cord *k′* is pulled the other rubber-covered roller (*c*) is brought into contact. The moment either end of cord is released the rollers return to their normal position out of contact. As the roller which is brought into contact is nearly a whole circumference from the point where the cord is let off, the cord has a good grip on the pulley, and never slips.

New Slow Motion in Right Ascension.—The recent advances in celestial photography have rendered it desirable to have a more delicate and accurate slow motion in Right Ascension than has hitherto been required. The necessity for this is partly due to the fact that up to the present no clock-work has been found sufficiently accurate to keep the star absolutely steady on the photo plate for the long period necessary to obtain an image of faint stars; and consequently it has been the practice

for the operator to have a very powerful finder-telescope with cross-lines set on a particular star, and to watch this star during the progress of exposure, and if he saw it vary its position by the smallest quantity to bring it back again by the slow motion of the instrument. Anyone who has experience in these matters will know how very difficult it is to obtain a slow motion which is perfectly certain in its action, has no back lash, and acts promptly, without and at same time setting the instrument into swing. The new slow motion which the writer has devised is not subject to these faults, and may thus be described :—

In the slow motion by differential wheels, described above, it is evident that if disc carrying pinion be simply stopped, a retardation or acceleration (according to relative positions of wheels) will be produced, to a slight extent. Suppose the wheels to have twenty-nine and thirty teeth, the speed will be altered $\frac{1}{30}$ part quicker or slower. Now, suppose two such differential sets of wheels be placed side by side on the shaft (which of course should be cut in two places), but with wheels so arranged that a stopping of one disc (and pinion) will produce an *acceleration* of $\frac{1}{30}$, and the stopping of the other will produce a *retardation* of $\frac{1}{30}$. A pair of electro-magnets working a clutch (or simple levers with strings) can be used to enable the operator, who has his eye applied to finder, to bring either the retarder or accelerator into action at any instant; and the action is so gentle that no swing or disturbance of the instrument takes place.

XVI.—A CLASSIFICATION OF THE SPONGES. By PROFESSOR SOLLAS, D.Sc., F.R.S.E., &c.

[Read, June 15, 1885.]

The Porifera are a phylum, divisible into the two classes—

I. [1]Plethospongiæ. II. Calcispongiæ.

The Plethospongiæ may be subdivided into three sub-classes—

i. Hexactinellida. ii. [2]Demospongiæ. iii. Myxospongiæ.

The Demospongiæ embrace the great majority of sponges, and are divisible into the two tribes—the Monaxonida and Tetractinellida.

The Monaxonida include as orders—(1) the Monaxona (Monactinellida, Auct.) and the Ceratosa, the latter clearly of polyphylitic origin, and derived from several families of the former; (2) the Tetractinellida include the orders Choristida (Sollas) and Lithisida.

The Myxospongiæ are not degenerate, but persistent askeletal forms, and include two orders—Halisarcosa and Chondrosiosa (excluding Corticium and its allies).

The classification, as far as the orders, may stand thus:—

PORIFERA (PHYLUM).

Class I.—Plethospongiæ.

Sub-class i.—Hexactinellida.		Order 1.—Lyssakina (Zittel). ,, 2.—Dictyonina (Zittel).
,, ii.—Demospongiæ	Tribe *a*. Monaxonida.	,, 1.—Monaxona. ,, 2.—Ceratosa (Grant).
	Tribe *b*. Tetractinellida.	,, 1.—Choristida (Sollas). ,, 2.—Lithistida (O. Scdt.).
,, iii.—Myxospongiæ.		,, 1.—Halisarcosa (O. Scdt.). ,, 2.—Chondrosiosa.

Class II.—Calcispongiæ.

[1] πληθος: a great number or crowd.

[2] δεμότηρος: common.

XVII.—THE RELATIONSHIP OF THE STRUCTURE OF ROCKS TO THE CONDITIONS OF THEIR FORMATION. By H. J. JOHNSTON LAVIS, M.D.

[Read, February 17, 1886.]

Introduction.—Two great questions of Vulcanology, of which our knowledge is still very limited, are in the first place the causes that bring about the wide range in force and character of volcanic activity; and, secondly, the difference in structure and composition of the resulting products. In the present Paper it is proposed to discuss a portion only of these very complex questions.

Those who have lived in a still active volcanic region, and have gazed over the landmarks of former activity, and compared them with those at present in progress, cannot but be struck by the evidence afforded of the enormous disproportion in the exhibition of volcanic energy from one time to another. Before 1631 the crater of Vesuvius was clothed with trees, brushwood, and grass, where goats were pastured, while the only sign of igneous action was the presence of two small lakes of warm water occupying the bottom of that depression. The quietness of this sylvan scene was only broken by the twitter of birds, the shepherd's chant, or the wind-rustled leaves. Let us compare this state of placidity, or still more that in which no sign whatever existed of the endogenous activity in the time of Spartacus, with those gigantic, prehistoric eruptions which tore away 1,000 metres or more of the mountain top, and hollowed out a cavity equal to a cone with a base diameter of three kilometres and a height of 1400 to 1500 metres. Even the Plinian eruption was an insignificant affair compared with its four predecessors. Between these two extremes in the vital activity of a volcano we have all stages of gradation.

Yet the phenomena of Vesuvius bear the proportion of child's play to a giant's exploits when we compare them with the catastrophe of Tomboro, Krakatoa, Cotopaxi, the Icelandic volcanoes, and many others. Meditating on these facts can hardly fail to awaken within us the inquiry as to the actuating cause of the variability in functions, if we may so call them, of a volcano.

Source of Energy stored up in Igneous Matter.—Disregarding for the time being the unsettled question of the condition of the earth's interior, let us assume[1] that we have an almost unlimited supply of igneous material; let us then ask ourselves, whether this material supplied in varying proportions is capable of producing an equivalent difference in the display and character of the volcanic forces. A moment's consideration will satisfy us that such is certainly not the case. There is no doubt that in a great *explosive* eruption a very large amount of matter may be ejected, but as it is always in the form of pumice its apparent bulk is larger than its real one. On the other hand, in paroxysmal eruptions we have enormous quantities of igneous magma ejected in a fluent form without exhibiting that amount of energy that occurs in the first case. If we compare the amounts, by weight, of matter (*essential*)[2] ejected during the Plinian eruption of Vesuvius with the lava outpours of 1631, we should find no ratio between them and the eruptive energy exerted on each occasion. Many still more striking examples might be given of the gigantic though comparatively quiet outflows of basalt when compared with low crater rings of the Eifel and other volcanic districts.

Were facts otherwise, so that the greater the eruption the greater the amount of material extruded, we should then have fairly conclusive evidence that the water which is the main motive power in a volcano was contained uniformly diffused throughout the igneous magma, as held by Rev. O. Fisher and others.[3] Of course we must admit that in distant regions such might really be the case, but it is not reasonable to suppose that it is so in a single locality, a necessary datum for such an argument. In consequence of this we are reduced to search for some local influences that are brought to bear upon an isolated portion of the igneous magma, and the only rational way in which we can suppose any such mass to be isolated would be when it has entered its duct on its way from its source to the surface.

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[1] This is compatible with all the more reasonable theories regarding the physical state of the deeper parts of our globe.

[2] I mean only that which is really extruded *de novo*, and not materials torn from the crater sides.

[3] *Physics of the Earth's Crust*, 1881, p. 187.

Passing over the older and more crude theories relating to the flowing[1] down of water by crevasses, and so coming in contact with the molten lava, or over the fantastic hypothesis of Davy down to that of Peacock, we find the question severely tackled in 1881 by three eminent geologists: Professor Prestwich,[2] who attributes eruptions to *the percolation of water to the porosity and cleavage planes of rocks*, and not to fissures, but yet does not admit of that intimate mixture of the water with the magma which anyone accustomed to watch the lava in its fluent state soon becomes convinced of. Professor Sollas[3] at the same time and place recognizes the intermixture of water and lava, and supposes the former to exist in the liquid state, but he fails to explain the variability of eruptive action except by relief of pressure. The changes of pressure, as explained by the author, are obviously insufficient to bring about inactivity on the one hand, or explosive[4] eruptions on the other. Besides, we should expect volcanoes in the same region to act quite synchronously. It is to Professor Judd that merit is due for the recognition of the fact that the igneous magma may, under pressure, absorb gases such as water is at high temperatures, and he gives in illustration a number of analogous examples, but does not treat of the conditions of absorption and dispersion of such water.

Just to this point we are provided with a demonstration of what is really the motive power of volcanic eruptions, and it is here I propose to take up the thread and discuss the conditions under which this water is absorbed, retained, and expelled.

Let us take an illustration, namely, the solution of carbonic anhydride in water itself. Carbonic anhydride is, at the normal temperature and pressure of the atmosphere, a gas; but by either increasing the pressure or lowering the temperature it may be reduced to the liquid or solid state. The water of volcanoes, at

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[1] Baron Dietrich in Ferber, Lettres sur la mineralogie, &c., de l'Italie, 1776, p. 207; also Braccini.

[2] "Some Observations on the Causes of Volcanic Action."—*Reports, Brit. Assoc.*, 1881.

[3] "The Connexion between the Intrusion of Volcanic Action."—*Reports, Brit. Assoc.*, 1881.

[4] It may be here mentioned that I do not use *paroxysmal* in the same sense as Scrope, but to indicate those increments of activity that occur from time to time during chronic activity, always accompanied by the outpour of lava, leaving *explosive* for those eruptions with only fragmentary pumiceous or scoriaceous pumice ejectamenta.

the normal pressure of the air and the temperature of lava, is a gas; and, like carbonic anhydride, may be rendered liquid or solid by increasing pressure or lowering temperature. By removing either of these secondary conditions the more volatile materials in the two cases return to their gaseous state. Now, carbonic anhydride in the presence of water is much more easily condensed, and dissolves simultaneously in that liquid, the solubility proportionally increasing with the pressure. Water is equally soluble in molten silicates, as is shown by its escape from lava, and its solubility likewise increases with the pressure, unless downright opposed to known physical laws. Between these two cases of gases soluble in liquids there is not only a physical, but also a chemical, analogy, for in both cases we have to deal with gaseous oxides soluble in liquid ones.

In the case of the solution of carbonic anhydride in water, and, in fact, of solutions of all gases in liquids, we find that the quantity of gas absorbed increases with the pressure, provided the liquid does not solidify (as exhibited in the spitting of silver). We find also that the pressure remaining fixed, an increase of temperature has a tendency to reconvert the condensed, or, more properly, dissolved gas, again into the gaseous state; or, in other words, we find that the tension of such a solution increases with the temperature. The absorption of oxygen by molten silver, and of the same gas and carbonic anhydride by iron and steel, as demonstrated by Troost, are familiar examples of fluids at high temperatures taking up gases. It is at the same time evident that the *critical point* of water no longer enters into the question, as it is held in solution like CO^2 in water, both occupying volumes much nearer their liquid than their gaseous state.

The conditions under which igneous matter commences its course towards the surface may, no doubt, be very variable, and whether such be due to secular cooling of our globe, and consequent straining and fracturing of its outer surface, it is not our present business to discuss. As already stated, we have every reason to believe the volcanic magma, as it exists in its original site,[1] contains dissolved in it little, if any, water, although many

[1] Whether this forms the centre of our globe, a stratum between the nucleus and crust, or exists as isolated reservoirs, in no way affects that part of the question now under discussion.

hold, on account of Sorby's discoveries, that the fluid portion of the earth's interior is an *igneo-aqueous* solution. We must first prove that granite, or at least that studied by Sorby and others, was not an intrusive rock in porous strata. In other words, it must be proved that granite is the *primitive* rock cooled without the intervention of secondary water.

It, therefore, on being transferred from great to lesser pressure, would only exert that small amount of expansion which is proper to its chemical components, which would therefore undergo no change of state, but remain as liquids under normal atmospheric pressure at the earth's surface. In fact, whatever expansion tended to take place in transferring the volcanic magma from great depths to the surface would be more or less balanced by the corresponding loss of heat, and consequent tendency to contract as a result of that, so that only a change in volume would take place, if any, in proportion to the different power of the two *agencies* to accelerate or diminish contraction. This theory of the solution of water in lava, and not lava in water, is incidentally mentioned by the Rev. O. Fisher.[1]

Extrusion of Igneous Matter through Dry, or nearly Dry, Rocks to the Surface.—Should such volcanic magma in its native state reach the surface, it might overflow without any explosive manifestations whatever, and consequently no cone of scoria or other fragmentary materials would be formed around the exit, and the locality of this would be only detected on a plain by the possible formation of domes, or mamellons, where the lava was sufficiently viscous. Neither should we expect such an exudation of fluid-rock to be accompanied by mechanical vibrations other than that dependent upon the formation of the fissure, or duct, by which the lava escaped, and which formation would be dependent upon causes extraneous to the actual expulsion of the fluid magma. That such favourable conditions may sometimes occur, so that the actual dyke may traverse strata that are not water-logged, we cannot deny, and possibly some of the great basalt plains of America and elsewhere may so have originated; yet, geology teaches us to consider such to be rather the exception than the rule.

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[1] *Physics of the Earth's Crust*, 1881, p. 190.

Intrusion of Igneous Matter into Dry, or nearly Dry, Rocks, but not reaching the Surface.—Should a fissure opening downward to the volcanic magma be formed by secular cooling or other means, we should expect that it would be simultaneously filled by the oozing in of the igneous magma. This mass of fused silicates, at a very high temperature, will now undergo a series of changes, which we will attempt to trace. The first thing will be the cooling of a layer of the magma, which is in actual contact with the walls of the fissure; and should that substance be in a purely vitreous condition, a pitchstone salband of variable thickness will result. Now, should the conductivity of the surrounding strata be great, or should the temperature of the magma be near solidification point, then that process will continue from the salband inwards through the whole mass, and a blind dyke will result. On the other hand, should the surrounding strata be bad conductors, already heated, and the magma at a very much higher temperature than that of its solidification, so that its heat might be given out quicker than the surrounding rocks could absorb, any salband that might at first have been formed would be re-fused, and such re-fusion might extend some distance into the surrounding rocks, continuing to do so until the supply of heat of the injected material was exhausted. Should the surrounding rocks be infusible, a chemical interchange would take place between the igneous and solid matter, resulting in the metamorphism of the former, and a corresponding change in the latter. Although I am not personally acquainted with many examples in illustration of this condition, probably some of those dykes which are so abundant in the Western Isles and Highlands of Scotland, described by Jameson and others who have followed him, will serve. If the intrusion of the igneous magma takes place in solid rocks, which themselves are at a high temperature from pressure—crushing or conduction upwards from below—three things will probably result. First, the magma, from the small absorption of its heat by the surrounding rocks, would require a very long time to cool, and that would also occur in a very gradual and uniform manner, so that an extremely course crystalline structure would result. This is the case in a great number of pegmatite granite veins. Secondly, no salband will be formed, and partial fusion of the fissure walls may occur, so that in gneisose rocks the line of

demarkation between them and the intrusive granite, or syenite, may be very ill-defined. Thirdly, the condition will be highly favourable to contact metamorphism, which, in such cases, often extends into the surrounding rocks for very considerable distances, often many hundreds, or even thousands, of yards.[1] Jukes maintained that the granite forms the basis of many volcanoes, being the source of the eruptive matter. It has been observed by Cotta, that the smaller the dyke the smaller the grain,[2] which is explained by the more rapid cooling of the smaller mass. We have the same in nearly all kinds of dykes, where the nearer we approach the outer surface the finer the grain; though volcanic dykes in cones are an exception for some minerals. Negri and Spreafico, in describing an expansion of porphyry near Lugano, show that the felspars near the surface are invisible, so that the rock is a euritic porphyry. Towards the centre of this great mass the crystals are distinct, but round and imperfectly formed, whilst in the dyke, which supplies this great mass, the crystals are very perfect and large, often reaching three centimeters in diameter. We see, therefore, that the perfection of crystallization, and the type of resulting rock, are in direct relation with the length of time and quietness of the cooling of the magma. In the same way we may explain the crystals in the salbands of some dykes, being smaller than those in the more central part.

On the other hand, we may meet with various intrusive rocks with more or less purely vitreous salbands, in which, in many cases, the line of demarcation is often distinct and very sharp between the dyke walls and the intrusive matter. There are also cases, as in the dykes of liparite of the Ponza isles, which possess thick pitchstone salbands which are soldered to the walls of the quartzose tufas. It would seem that the great resemblance of the two rocks in chemical and mineralogical composition, and therefore the small difference between their points of fusibility, a very slight excess of temperature in the intrusive rock would be sufficient to fuse the walls, and yet cool rapidly enough to prevent complete crystallization, thus leaving the vitreous salband. This is aided, no doubt, by the low heat conductivity of the surrounding tufas.

[1] L. Gatta, Vulcanismo, 1885, p. 28.

[2] Naumann, Lehrbuch der Geologie, 1858–1868.

Even in granite, although there is no vitreous salband which would be incompatible with its coarse, well-crystallized structure, Naumann describes granite dykes in which the grain is finer towards the margin.

It seems probable that where intrusion takes place into rocks, the cleavage planes of which are nearer the horizontal in direction, the loss of heat will take place slowly, and we should expect to find coarse-grained granites and trap rocks; whereas, the more the cleavage planes approach the vertical the greater will be the rapidity of cooling. This is a question well worth inquiring into, for Jannettaz[1] has shown that the major axis of the isothermic ellipsoid in crystals is parallel to the principal planes of cleavage, and in rocks with the planes of schistosity.[2]

Intrusion of Igneous Matter into Porous Aquiferous Strata.—The same results as in the last case may be looked for, but we shall see that superposed upon them there is another series of far greater importance. Let us suppose the fissure formed, injected, and that a salband has solidified. The water in the immediate neighbourhood will tend to increase in temperature until it arrives at the same degree as that of the lava, since in most cases the enormous superincumbent pressure will have proportionally raised the boiling point. Then again, as the water exists bound up, as it were, within the pores of some permeable rock, little convexion circulation is permitted, at the same time that expansion to the gaseous condition furthermore is resisted. This shell of superheated water is only separated from the igneous magma by the salband, which according to varying circumstances may differ very much in thickness, and so will act as a more or less imperfect porous septum between the igneous matter and superheated water. Although probably not possessing exactly the same physical characters as the porous septum in dialysis, nevertheless it no doubt would permit diffusion to go on between the two fluids which it separates, or even the porous rocks themselves may play that part. Besides, we have another

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[1] Mémoires sur la propagation de la chaleur dans les corps cristallisés (Ann. Ch. et Ph., 4° serie, t. xxix., p. 5; Bull de la Société Géologique de France, 3° serie, t. I^er et suiv.).

[2] As the stratification of strata in general approaches nearer to the horizontal than the vertical, the conditions will be most favourable for the retention of the internal heat of our globe.

striking resemblance to the process of dialysis, for the igneous magma is in a vitreous state, which we may take as the representative of the colloids,[1] whilst the superheated water in all probability may still be regarded as a crystalloid. In consequence of this we should look for endosmosis as the principal function, although the metamorphism of surrounding rocks, which in the case of the existence of salbands is comparatively slight, would indicate some amount of exosmosis. In the case of the blind fissure being converted into a channel through which the igneous magma circulates, then no doubt the salband would, in most cases, be refused or carried away by other means, and the permeable rocks would then play the part of the septum. In fact, even in a blank fissure we can comprehend that no salband may exist.

The rapidity of this endosmosis of water, and its diffusion through, or solution in, the colloidal-like magma, will obviously depend upon a variety of circumstances, such, for instance, as the composition of the magma, the form of fissure, and therefore amount of surface exposed, pressure, &c. This we see portrayed in the illustrations we chose; for if carbonic anhydride is in contact with the calm surface of water solution takes place very slowly. A knowledge of this fact is practically made use of in the seltzer-water machine, in which a number of lashers revolve with great rapidity in a chamber filled with water and the carbonic anhydride, so that a very large surface of each is brought into contact by the churning motion, and consequently solution takes place with very great rapidity.

But to return to the main question, this absorption of water will go on at the expense of heat to the igneous magma, which, however, will only lose so much as will raise the amount of water absorbed to its own temperature. This loss will not, of course, be very great, since there is no conversion of a liquid into a gas. Nevertheless this loss of heat, combined with that due to the conduction away by the surrounding rocks, may be so great that the igneous magma may reach its point of solidification, and further action will be prevented by the fissure being now filled by a cooled rock mass.

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[1] At any rate as far as the silica, and probably the alumina and iron oxides, are concerned.

On the other hand, should such not have taken place, as the amount of water absorbed increases, the tension of the fluid mass will proportionally do so also. There will arrive a time when the tension of the fluid mass will exceed the resistance of the surrounding rocks, or the superincumbent pressure, which will result in the rending asunder of them and the extension of the fissure. Such extension may be sufficient to make it reach the surface forming the site of a volcano, or as it extends and gives place for expansion the tension may proportionally so decrease until the balance is restored before the surface is reached. The extension of such a fissure will rather tend towards the surface, as least resistance would be encountered in that direction.

Such an extension of a fissure will give rise to two or more very distinct series of vibrations: first, we shall have slow ones extending over a considerable length of time, due to the gradually increasing compression around the expansible matter which, if apparent at the surface, would assume the characters rather of tilt than that of an earthquake. Local elevation of a small area such as occurred at the Starza of Pozzuoli, pending some years before the outburst and formation of Mount Nuovo, or the same thing at Torre del Greco in the Vesuvian eruption of 1861. The actual rending and enlargement of the fissure will give rise to a series of vibrations of small amplitude, such as are first registered in an earthquake.[1] These will be immediately followed by the sudden arrest of expanding matter coming in contact with the walls of the fissure, which space it injects immediately. The effect is well imitated by allowing steam to escape from a boiler under high pressure, and suddenly closing the opening. Other examples are the sudden injection by water of a blind and collapsed hose, or the rapid closing of a tap from which was flowing a stream of water under pressure, conducted through a pipe of some length. This impact of the fluid matter against the solid fissure walls is followed by a series of diminishing oscillations or throbs. This group of disturbances no doubt constitute the more powerful or destructive portion of the earthquake, and the character of these vibrations,

[1] J. A. Ewing, Earthquake Measurement, *Mem. Sci. Depart. Univ. Tokio.*, No. 9, p. 54, and following.

which we should deduce on the above theoretical grounds, completely coincide with earthquake registration.

The extension of the fissure may have been sufficient to allow of the formation of steam, which may collect together throughout the pasty mass as bubbles; and, should solidification soon follow, the resulting dyke-metal would present a vesicular or amygdaloidal structure. On the other hand, the expansion may only have taken place to such a point, that no conversion of liquid into gas has taken place, and as a result we should look for, in case of solidification, a dyke presenting no signs of vesicularity. The finding of a dyke-metal, in which no vesicularity is manifest, is no proof that at some time it may not have had such; for, were cooling not to follow soon on vesicularization, the renewed gradually increasing pressure would again compel the steam to redissolve in the magma. These facts probably account for the rarity of a vesicular state of granite, though even this is sometimes known to occur as in the island of Mull, and that of the plateau of the *Palais du Roi*, Lozère, described by Lecoq.[1]

Under the two former circumstances we should expect the first to end in solidification more often than the second; for, by the conversion of the dissolved water into steam, a very much larger amount of heat would be used up, proportionally of course to the amount of conversion that took place.

By the progressive extension of the fissure a larger area of igneous rock surface will be exposed to the conditions which have been described, so that the tendency will be towards the more rapid absorption of water, and consequent crisis between tension and resistance. Besides, from the larger amount of expansive matter capable of acting, the effects will be more violent each consecutive time.

The facts are borne out in such examples as Jorullo and Monte Nuovo, and are now probably in progress under Casamicciola, in the island of Ischia. In such examples we find, that for a long period earthquakes occur at distant intervals, but that these have a gradual tendency to follow each other progressively more often, and often increasing in destructiveness at one spot, although the area affected may proportionally become more concentrated. At

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[1] Les époques géologiques de l'Auvergne, I., page 465.

last the frequency may become so great that the intervals are almost imperceptible until the fissure reaches the surface, and the igneous matter finds a vent for its expansion.

Of course the sheet of igneous magma may solidify at any part of its journey towards the surface in consequence of—

(*a*) Loss of heat from conduction away by the surrounding rocks.

(*b*) Raising the acquired water to the mean temperature of the solution of silicates in which it is dissolved.

(*c*) By loss of heat in consequence of expansion during the extension of the fissure.

(*d*) By gradual escape of water in the form of steam or vapour through fissures so supplying fumaroli.

(*e*) By convection currents of waters forming Geysers or thermo-mineral springs.

It is a common fact that the water-bearing qualities of different rock strata are widely different, and we also know that an igneous dyke may traverse an alternation of more or less permeable strata. Where the supply of water was greatest, conductivity and other things being equal, there would take place the greatest amount of diffusion of that liquid through the igneous magma. Were this latter a perfect fluid, and non-viscous, the more aquifarous, probably lighter, part would soon diffuse itself in all directions, rendering the whole a homogeneous mass. We know, however, that all lavas are exceedingly viscous, especially the more highly silicious ones, and therefore such diffusion would take place very slowly. This would be aided by the upper part of the column being lighter, from that portion being placed under the more favourable conditions for absorbing water.

The more porous the strata the greater the tendency will be for the conduction away of the heat of the magma, either directly or by the aid of convexion, currents of water, or by the conversion of the latter into vapour, where pressure is so low as to permit it.

Extrusion or Eruption of the Igneous Magma into the Atmosphere.—If we suppose, simply for the sake of brevity of argument, the lava canal to be a tube of uniform size between the source of

igneous matter and the surface (which, however, it never is), and that such a canal traversed rock strata of different permeability; then the magma enclosed in the tube would consist of a series of more or less saturated aquiferous strata, superposed on each other in the same order in which each part was exposed to a portion of the canal wall. Now, should a sudden exit of magma occur from the tube at its upper extremity, the expansion, or, in other words, eruption, would take place with a violence directly proportional to the amount of dissolved water, and the temperature of that portion of the mass nearest the surface, at different periods of the eruption. The eruption will therefore lull or augment, as that portion, being expelled originally, occupied a more or less favourable site for the absorption of its contained volatile matter. The examples given at the end of this Paper seem to indicate that this departure from what is a normal type of eruption of a truly homogeneous magma is of rare occurrence. My experience in the field has been chiefly drawn from the basic volcanoes of Vesuvius and Roccamonfina (Leucite basalts), Mt. Vultura (Haüyn basalt), Mt. Nuovo (Phonolite), Ventotene and San Stefano of the Ponza group (Andesite), and Ischia (Trachyte). Were the suppositions in the above case true, and were the entire chimney or canal completely emptied in each eruption, then we should expect every stratum of ejectamenta representing an eruption to be composed of a series of components alternating with each other in direct relation with the eruptive variations, and with the structure of the earth's crust beneath the volcano. Besides, in any one volcano, we should expect each stratum of pumice to be made up of analogous components to those produced during eruptions that preceded and followed it, indicating the same train of variations of activity, which is not the case. Geological evidence, so far as denudation has opened up to our examination the old remnants of igneous dykes and chimneys, leads us to conclude that igneous canals assume very irregular shapes, winding about where least resistance was offered to their extension, but nearly always assuming the form of a plate-like mass choking a fissure. Such fissure we know may have a horizontal extension of many miles. The opening or openings at the surface would be very local, and therefore the exit of the igneous matter would tend to take the form of a fan-shaped current with the point of orientation at the exit. Under

such conditions the order with which differently exposed parts of the fissure's contents reached the surface would be most complex, depending on a large number of collateral circumstances. The tendency will be to shade off sharp irregularities of composition, and render the magma more homogeneous.

The Main Varieties of Volcanic Outbursts.—Whatever type of activity the volcanic outburst may have taken, we have only so far discussed secondary variations therein, and it now remains to explain what is the acting cause in different varieties of eruptions.

It is necessary that we diverge from our train of argument to refer to some of the physical phenomena accompanying the relief from pressure of a superheated liquid. Sir G. B. Airy and Prof. Rankine[1] showed that in the explosion of a steam boiler the destructiveness was not due to the expansion of the steam already existing enclosed within it, but as soon as the pressure on the superheated water-contents diminishes, that liquid undergoes rapid and violent evaporation, until by such action the remnants are reduced to the normal boiling-point of the locality of the boiler. Mr. G. Biddle has demonstrated that, in a boiler containing steam and water at a pressure equal to four atmospheres, when the source of heat was removed, and the pressure suddenly relaxed, one-eighth of the whole liquid contents was immediately converted into the gaseous form. Prof. R. H. Thurston,[2] who has lately worked at the same subject, has shown that although the energy stored in the steam contained in a boiler is far in excess of that of the water at the same temperature, the amount, by weight of the latter, is often proportionally so much greater that it represents an enormous amount of stored energy. He showed, however, that as the temperature rose, the more the energy stored in the water approached that of the steam: at 50 lbs. pressure the ratio is 20 to 1; at 100 lbs., 14 to 1; at 500 lbs., 5 to 1; while at 7500 lbs. the two quantities become practically equal. At 60 lbs. pressure, 1 lb. of steam equal $\frac{1}{3}$ lb. of gunpowder; but at very high temperatures, at which steam and water are equal to each other, they rival gunpowder.

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[1] *Phil. Mag.*, November, 1863.

[2] *Trans. American Soc. of Mechan. Engineers*, 1872; and *Journ. Franklin Inst.*, December, 1872.

These facts are of extreme interest in relation to volcanic activity. At the enormous pressure and temperature that an igneous water-bearing magma may exist, the dissolved water equals, or exceeds in energy the same weight of steam or gunpowder. We also see that the crater-forming and eruptive power will be in direct proportion to the amount of superheated water existing in the magma; and crateriform hollows of ten miles in diameter are not difficult of comprehension. In fact, it seems somewhat astonishing that such excavations are not far greater, when we think of the terrific energy that may be stored beneath us in the form of such enormous dykes as those great masses of diabase in the region of the Hudson river. The great difference between the two conditions is, no doubt, that the water in the boiler is perfectly free to evaporate, whereas in an igneous magma it is molecularly scattered through the viscous mass, so that although the energy stored in equal quantities of water in either condition would be the same, the dispersion will be spread over a longer time in the case of the paste, due to retardation of escape in consequence of viscosity.

In the author's recent researches on the past and present eruptive phenomena of Vesuvius[1] certain important facts were brought out which it has been possible to confirm in a large number of instances in other volcanoes. When this volcano is in a state of chronic activity, with short intervals between one eruption and another, the violence with which the ejections take place is small compared with what occurs after long periods of quiescence. Thus, for instance, during the building up of the old mountain, and again during the last two to three centuries, we find that a very large portion of the products consisted of continuous masses of lava, whereas in the great explosions that excavated the gigantic crater of the Atrio del Cavallo, and which, from the interstratification of vegetable soils, and denudation marks, are proved to have occurred at long intervals apart, are characterized by deposits of spongy pumice, with a total absence of anything but fragmentary products. But in the above case we have not only geological, but even historical, proof; for we know that at least for many centuries before A.D. 79 this volcano had

[1] *Quart. Journ. Geol. Soc.*, January, 1884.

been apparently extinct, and that in the great Plinian eruption we had nothing but spongy fragmentary varieties of its usual igneous rock. The eruptions that followed the Plinian one occurred at diminished intervals, and so the more did their products approach in structure that of the lava of chronic activity, until, in the tenth century, pumiceous materials formed no longer, at any rate as far as the *essential* ejectamenta go, the products of these eruptions. To take another example, the precedents and whole history of which is pretty well known, namely, Monte Nuovo. We find that the main mass of the mountain is built up of pumice in various stages of comminution; capped, or covered, by more compact and crystalline scoria, or lava, fragments, which were only ejected at the last, when the volcano tended to pass into the chronic condition. We also know that such volcanoes as Tomboro, Krakatoa, and others like them, after a long quiescence burst forth with an amount of violence to cause disturbances throughout our planet, produce ejectamenta that are always of pumiceous character.

These facts, I think, give us the clue to the real sequence of phenomena which lead up to, and result in, the different varieties of eruption. Let us suppose that an extensive igneous dyke has, from some circumstances which will be discussed later on, become plugged at the exit on the earth's surface. The part of the magma that retains a sufficiently high temperature will be gradually absorbing water; and as assimilation proceeds the tension of the magma will proportionally increase, and the temperature of the mixture reduced, so that in some cases this loss will gradually favour solidification of portion of the magma forming the crystals of the felspars, Amphibole, Biotite, and other micas, &c. Such a state of things will go on until one of two things takes place—either the loss of heat be such that the whole igneous mass solidifies, or, on the other hand, the tension overcomes the resistance, and an eruption takes place.

Other things being equal, we should expect the violence of the outburst to be directly proportional to the length of contact of the igneous magma with water-bearing strata, or, in other words, the longer the quiescence the greater the violence in the subsequent eruption.

The diffusion or solution of water through the igneous magma

will diminish in a progressive manner as saturation increases. The amount that may be taken up is demonstrated by the enormous volumes that escape during an eruption. Were it possible to calculate the amount of vapour expelled during any great eruption, and to estimate the solid ejectamenta—also a difficult matter—these added together would give us the composition of the paste immediately before its expulsion, unless we have the level of the magma surface below that of the drainage-line of the country, in which case the vapour would be increased by the inpour from the porous walls of the chimney, and a pulverization of such water similar to the action of a spray apparatus, when the amount of vapour expelled might be enormously augmented. Such calculations have rarely been attempted. Cavalleri[1] estimated that from Vesuvius, in 1856, during a period of eighteen months, pending which the strombolian state of activity had persisted, that no less than 407 millions of cubic meters of water had been ejected in the form of vapour. We may form an idea of the mass by imagining a lake $6\frac{1}{3}$ kilometers square, and 10 meters deep. I cannot form a just conception of the amount of vapour issuing from Vesuvius on the above occasion, but from a long and intimate acquaintance with this volcano during the last six years, it seems to me that the above calculation is greatly in excess of the truth, such a result being quite comprehensible when we take into consideration the almost insurmountable difficulties of finding suitable data to go upon. If we form a conception of 516,500 kilogrammes of water escaping every minute in the form of vapour from an aperture of four or five meters in diameter at the most, it certainly seems the feeble state of strombolian action would be out of the question.

It was also calculated[2] that 22,000 c. meters of water were daily dispersed in the form of vapour by the lateral openings of Etna in the eruption of 1865, that is, equal to 2,000,000 c. meters, for 109 days that that eruption lasted. This estimation, which, I believe, is that of Fouqué, certainly appears more reasonable than the former.

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[1] Considerazioni sul vapore e conseguente calore, &c. Memoir read in the Accad. Fisio-medico-statistica di Milano, December 27th, 1856.

[2] Quoted by M. Ch. Vélain. Les volcans ce qu'ils sont et ce qu'ils nous apprenent. Paris, 1884, p. 45.

One is apt, however, to attach a greater value as regards quantity to volcanic vapour, from the peculiar molecular state which it assumes immediately on its escape, which is probably due to conversion of the steam into vapour, by the process investigated by Dr. Aiken. Everyone is aware that our breath in the hottest weather is converted into a white cloud when near the vapour of of HCl. Nevertheless, whatever value we may put upon the above calculation, we cannot do otherwise than comprehend the very large amount of water that may disengage itself from the igneous magma.

In the case of a fissure whose upper limits are very far beneath the surface, and suddenly extends thereto, we should expect the eruption to be less violent than were the magma in closer proximity; since a large part of the energy of tension would be lost in the expansion in injecting the extension of the fissure.

Conditions which may determine an Eruption.—In a large number of cases the gradual increase of tension in the confined magma may go on to the crisis of eruption. But in certain cases the intervention of collateral influences may anticipate such an occurrence. An increase of upward pressure from the main volcanic source, dependent upon secular cooling, tidal action (if such exists), or other causes, may be sufficient addition to the amount of tension already existing to more than balance the resistance. A sudden lowering of atmospheric pressure may be sufficient in some cases to render the superincumbent pressure less than the tension of the igneous magma. It is known that, as the rainfall is increased in the season, the drainage level of a country reaches a higher line, and therefore the superincumbent pressure increases; and, *vice versâ*, the superincumbent pressure diminishes during a drought, so that a sudden relief of pressure may be the metaphorical *last straw*.

The greater the height in a temporarily extinguished volcano the greater the weight, or, in an active one, the greater the pressure of the superincumbent column of lava above the drainage level.[1] We might therefore say, that as a permanent volcano increases in height its eruptions will diminish in frequency to increase

[1] Let us compare the height of a column of phonolite paste of 100 (?) meters of Monte Nuovo with the column of heavier doleritic paste of Etna of 3300 meters, when we see that this is an important factor in modifying the eruptive character of a volcano.

in power—a fact thoroughly borne out by experience. Under the same conditions, in a lateral opening of a very high volcano, such as Etna, the amount of lava will be greater as the chimney is higher above the outlet, since it will hold more. But beyond this, the amount of output will be more than that contained in the chimney above the level of exit, but also indirectly as the pressure of that amount is removed. When the lava pours out laterally from the chimney, its superincumbent weight, being removed, will allow expansion of the elastic matter below the level of exit, so that as this rises to establish a balance, lava will continue to pour out from the lateral outlet until total equilibrium is obtained. In this way the amount of lava spread over the surface will be much more than that contained in the chimney above the level of the exit. This fact I have been able to verify on various occasions in the recent small eruptions of Vesuvius, which are in many ways more instructive than great ones on account of permitting near approach to be made. This, I believe, will eventually be proved to be the true mechanism of lateral eruptions. As examples, we may compare the bulk of the lava products from the lateral craterets of Vesuvius and Etna.

Conditions which determine the Extinction of a Volcano.—We have already seen how a dyke that has not manifested itself at the surface may solidify, and so divert igneous action to other localities. In the case of explosive eruption, the expansion that takes place in the magma increases its volume, in the form of a pumiceous froth, to such an extent that it occupies many times its original volume.[1] A large portion of this spongy magma escapes, leaving the fissure still filled to such depths as to the point where expansion would be prevented, choked, as it were, by this vesicular paste, which may even have solidified by the loss of heat in volatilization, and so may effectually have plugged up the exit. Some such process would really seem to occur in eruptions like those of Krakatoa. We have an illustration of this in opening a bottle of champagne *well up*, in which case more than half the liquid contents may escape in the form of froth. In the expanding magma there would be no distinct line of demarkation between the pumiceous,

[1] The volume of steam at 100° C. is 1696 times that of water at the same temperature.

or frothy portion, and the still continuous fluid mass beneath. If, from the want of supply from below, this does not rapidly rise and issue as a lava, it may go on gradually giving up its dissolved water in that state, and by loss of heat may solidify and prevent, at any rate for some time, eruption at that particular volcanic vent. In the types of tranquil activity, either strombolian or in the case of occasional outpours of lava,[1] we have three main agencies at work. In the first place, the aqueous matter contained in the magma will be dispersed, proportionally lowering the temperature. At the same time, the magma may be absorbing fresh water, raising it to its own temperature, and eventually converting it into vapour, which continues to escape at the expense of its own heat. Last, and probably least important, would be the conduction and convexion near the earth's surface by the subterranean circulation of water.

The Presence of Volatile Matter in Modifying the Structure and Composition of Igneous Rocks.—As has already been intimated, those grand explosive eruptions that burst forth after long intervals of complete tranquillity are characterized by an *essential* ejectamenta of vesicular structure and fragmentary state. On the other hand, chronic activity, even when it increases to the stage of paroxysmal outbursts, is equally well marked by the outflow of a continuous mass of igneous magma, or what is generally known as lava. The vesiculur rock masses, or scoria, that cover lava streams are, both in origin and structure, widely, though not completely, different from the pumiceous products of the first kind of eruption. These assertions hold true almost without exception in the case of basic rocks, and are exceedingly common even amongst the most acid ones. Most of the illustrations that will be brought forward have been chosen from among basic rocks, since, so to speak, *crisis* between a vitreous, fine, vesicular, and fragmentary state on the one hand, and a crystalline compact continuous mass on the other, is easily attained, and is well defined.

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[1] The paroxysmal eruptions of Scrope, Volcanoes, 1828 and 1862.

Monte Somma Vesuvius.	Roccamonfina.	Monte Vultura.	Monte Nuovo.
Phase ? Introductory explosive stage. Problematical.	Same.	Same.	Introductory explosive stage. At first, ejection of highly vitreous and microcrystalline (excluding plutonic - formed minerals) pumice followed later by more compact and almost continuous outflow of Phonolite.
Phase I.—Chronic activity, outflow of leucitic basalt, lava, scoria, ash, &c.	Same.	Same. Outflow of basalt, Haüyne basalt, and leucitic basalt.	Apparent extinction.
Phase II.—Inactivity, denudation.	Same.	Same.	
Phase III.—Violent paroxysms, dwindling into next phase. Production of basalt pumice and pumiceous scoria towards the end.	Same. Production of leucitic basalt pumice and pumiceous scoria towards the end.	Same. Production of Haüyne basalt pumice and pumiceous scoria towards the end.	
Phase IV.—Apparent return to chronic activity. Leucitic basalt lava (small in quantity).	Same. (abundant.)	Same. (Abundant production of Haüyne basalt lava.)	
Phase V.—Inactivity, denudation.	Same.	Same.	
Phase VI.—Violent explosive eruptions. Production of basalt pumices.	Same. Production of andesitic ash in enormous quantities.	Semi - explosive eruptions of pumiceous scoria, forming the present lake basins. Haüyne basalt very similar physically to Phase VII., period 5 of Vesuvius.	
Phase VII.—Less violent, dwindling into next phase. Production of leucitic basalt pumices and pumiceous scorias towards the end.	Eruption of large quantities of andesitic lava.		
Phase VIII.—Chronic activity, outflow of leucitic basalt lava.			

From this Table we learn that a series of intermissions take place in the activity of a volcano; that following these intermissions we have the production of fragmentary pumiceous ejectamenta, which, by gradual stages, pass through a pumiceous scoria stage to that of true lavas. The striking resemblance between the phenomena of the three first-named volcanoes up to a certain stage cannot but strike the observer as very remarkable, and opens a wide field of investigation, for it is quite certain that similar stages in each of these volcanoes were not contemporaneous.

The igneous magma, whilst confined below, may have undergone partial crystallization before it reaches the surface. In that case, however rapid the ejection and cooling be, the ejectamenta will always contain those *formed* materials, as seems to have been the case with sanidine, amphibole, and, perhaps, other minerals in all the pumices of Vesuvius, Mt. Vultura, Roccamonfina, the Campi Phlegrei, Ischia, &c. In case of the magma containing a large amount of diffused water, the sudden and rapid conversion of this into the gaseous state will immediately result in the conversion of the magma into a spongy mass, splitting it up into fragments of various sizes by the partial escape of the gaseous contents, and rapidly absorbing an enormous amount of heat. In consequence, the mass solidifies before time is given for the conversion of the vitreous into the microcrystalline or crystalline state, or, at the most, only allows such to take place imperfectly. As a result of the rapid solidification, many of the bubbles of gas are unable to escape from the mass, except where near the surface. We must remember that the change of pressure is not only from that of the original magma to that of the atmosphere at the earth's surface, but the low pressure reached, by the ejectamenta, many thousands of feet, or even some miles upwards, to which height the materials are projected; and even if that were not sufficient, the rapid cooling by contact with the cold air in falling would complete the refrigeration. That such is really the case we have certain proof of in the preservation of organic and easily fusible substances of Pompeii. The actual physical structure and mineral composition of a pumice will depend on—

(*a*) Composition of the original magma.

(*b*) Pre-eruptive temperature of same.

(*c*) Amount of enclosed volatile matter.
(*d*) Amount of pre-eruptive crystallization.
(*e*) Rapidity of ejection.
(*f*) Height of projection.
(*g*) Temperature of the air.

The ejection will take place at first with great rapidity, but will diminish as the tension in the whole unescaped mass is relieved. But beyond this the upper portion of the injected igneous magma column will be more exposed to aquiferous strata than that farther removed from the earth's surface; and consequently the expansion, and the results dependent upon it, will be most marked in the portion of the magma near the surface, and also it is probable that that part richer in water will be lighter, and rise to the top of the column. This part having escaped, those portions that follow it will be hotter from diminished loss of heat, from the less amount of diffused water it has raised to its own temperature, and also from the less water to be converted into steam: the latter will escape more slowly, and will reach a less height, all circumstances favourable to the slower cooling and less vesicularization of the magma. The consequence is, that we must expect more crystalline and denser ejectamenta generally in larger fragments, which I have called pumiceous scoria. Should the eruption not terminate at this point, the conditions favourable to slow cooling, more complete crystallization, and continuity of mass, may proceed to such a point that the igneous magma may pour forth from the vent, forming lava streams of vast extent, so that years may be occupied in cooling, or the magma may be kept simmering in the volcanic chimney, presenting the characters of strombolian action. Monte Nuovo is a good illustration of the former case, although the lava hardly reached the point of flowing out as a continuous mass. The progress of events, as above described, is fully borne out by the investigations of the physical structure and composition of rocks, whose mode of formation we can judge of by historical accounts, by collateral facts, and by analogy. I first discovered that an eruption of explosive type produced a deposit of pumiceous nature, divisible into three sections, at Vesuvius,[1] and I have been able to

[1] "Geology of Mt. Somma and Vesuvius," &c., *Q. J. Geol. Soc.*, Jan. 1884.

verify the same facts at Roccamonfina, Mt. Vultura, Monte Nuovo, San Stefano, Ventotene, Ischia, and many other volcanoes, in at least a hundred different eruptions. In the second part of this paper I propose to bring forward typical examples from each locality in illustration of this. For the present, however, we may state the divisions as follow :—

1. Ejection of vitreous froth, which rapidly solidifies, as pumice; all the minerals that occur crystallized are of plutonic separation, as sanidine, biotite, amphibole, &c.

2. Microcrystalline pumice, in which surface cooling has produced pyroxene and leucite. The amount of vitreous base diminishes as we reach the top of this division, and is replaced by *formed* material.

3. The pumiceous ash-bed in which the cementing vitreous base is nearly all destroyed, so that cohesion has become so feeble that the formed matter separates, producing an *ash* composed of crystals and microliths. The difference is very similar to the results of crystallization of a salt in the form of large crystals by a slow process, or, in the preparation of the granular state, by a quick one, as table salt, pure Ferrous sulphate, and oxalic acid, as they are met with in commerce.

The increase of the percentage of silica has the effect of rendering acid-rocks less easily crystallizable, just as the amorphous form of sugar retards crystallization of other bodies with which it is mixed. For the same cause, the viscosity of the rock is increased, so that the escape of the enclosed gaseous bubbles takes place with greater difficulty; and, as a result, the pumiceous character is far more common amongst such rocks.

Mode of Formation and Structure of Scoria.—This product, which is often erroneously grouped together with pumice, is that spongy variety of lava which covers or underlies a stream. When the magma does not contain sufficient volatile constituents to tear it asunder before it issues from the volcanic vent, it will pour down the slopes of the cone, giving up what remnants of aqueous matter are still dissolved within it. Should this be considerable in amount, and the temperature of the lava rather low, in basic examples we shall get an irregular broken-up cinder-like mass, that will continue to float on the surface, and cover it in some

cases to a great thickness. Prof. Judd, who fully appreciates this fact, gives a striking example of this side by side with an equally interesting illustration of the opposite condition. On the contrary, should a basic magma be remarkably devoid of dissolved water, its surface will not be broken up, and it will assume forms like any other viscid body in movement. In the case of a water-bearing acid lava, the scoria surface will be much thicker, on account of the difficulty with which the gaseous materials escape in consequence of the viscidity of the paste; whilst in nearly non-aquiferous acid lavas the surface figures that result will be more marked, and more characteristic of an intensely viscous magma, as illustrated in the mammelon volcanoes, such as the islands of Reunion, Hawaii, the obsidian stream of Vulcano, or some of the central French groups. On the other hand, the Vesuvian lavas of 1858 and 1872, as pointed out by Judd, are respectively typical of aquiferous and non-aquiferous magmas, which may be further illustrated by the trachyte of Monte Olibano, and the Lava del' Arso of Ischia.

From the mode of formation of scoria we must expect it to exhibit two very marked differences in structure and mineral composition from pumice. In the latter the vesicular cavities are of all sizes, ranging down to the minutest dimensions, which are the most abundant and marked characteristic of pumice. This is due to the intermolecular separation of steam and its union *sopra loco* into vesicles of varying dimensions. In the case of the scoria, the gases are derived from the whole thickness of the subjacent lava, which, in rising in the mass, further unite together, so that the cavities are rarely of microscopic size, and may reach very great dimensions; and unless the bubbles be of a certain size, the large area of their surface in proportion to their volume increases, so that the friction is so much that they could not rise in the viscid mass. In the case of pumice we have the vesicular structure developing in a complete or nearly vitreous magma, which is the principal cause of rapid solidification; but in scoria the bubbles of hot gas that rise from the bottom, which, from being more protected, is the hottest part, through a magma already far advanced in crystallization, would help to prevent or ward off the cooling of the surface. Besides, the scoria will cool slowly, resting as it does on the surface of a highly-heated mass. We therefore may sum

up by stating that pumice is filled by vesicles of all sizes, but mostly small, and approaches the vitreous state, whilst scoria only contains vesicles of large size, and approaches a crystalline structure. The ejectamenta during strombolian action is a true scoria, being dependent upon borrowed steam that rises in the magma column, and forms the vesicles.

In lavas the presence of vesicular cavities is no proof of the actual amount of original vapour, for the latter will be allowed to more easily escape in a microcrystalline mass, such as that of 1631 of Vesuvius, which is a very compact rock, yet gave forth enormous quantities of vapour as almost to resemble the explosive type of eruption. The lava of 1858, which is rich in large leucite crystals and much interstitial glass, is a remarkable spongy structure, because its viscid nature prevented the escape of the few included bubbles of vapour, which, compared with others, was remarkably small in quantity in that eruption, affording compact types of lava surface. This escape of vapour may so separate the constituent minerals of a scoria surface as to leave it in a perfectly incoherent and pulverulent state. This I have seen in some of the trachytes of Ischia, and of the Solfatara (Monte Olibano).

Another fact is, that lava as it pours out that portion which is nearer the surface will, in all probability, be the richest in water, and will produce a stream thickly covered with scoria. But as the portion which comes from greater depths rises it will have been exposed for less time to aquiferous rocks, and in consequence, containing less water, will produce a smoother-surfaced stream. This was remarkably the case in the Vesuvian eruption of 1855;[1] the first streams that issued were much rougher than those at a later date.

The conditions under which the composition of Igneous Rocks is modified.—One of the most vexed questions in geology is undoubtedly that of the variation in an igneous rock, and more especially with regard to its chemical than its mineral composition. Space forbids here to enter fully into the theory of stratification of magmas, as represented by Von Richlhofen and others. No distinct division can be drawn between rocks derived from the most acid, and the ultrabasic magmas, showing that they can mix in all proportions. Then again, whatever be the silicates we may fuse

[1] Memoiria s. Incend. Vesuvio, 1855, G. Guarini, L. Palmieri, and A. Scacchi.

together, none of them separate from each other, however long they may be kept in the fluid state. Thirdly, all magmas may be looked upon as originally mixtures of fused oxides, some basic and other acid, it is true; but in either extreme types there is a certain amount of intermixture. We find such substances as the fats, mineral oils, chloroform separating from water, or mercury from either; but we must remember that these incompatibles are built up of molecules, arranged on entirely different plans, which is not the case with the constituents of volcanic rocks. It may seem improbable, but I feel sure that time will show that the active cause of various rock composition, at any rate, to a certain extent, will be proved to result from some chemical changes brought about between an isolated portion of an original common magma and the neighbouring rocks. Also the infiltration of saline solutions may result in the bases of the contained salts, combining with the silica, and liberating the original acids. The facts that support such a theory are certainly few, but also those that can be urged against it are equally so, and in most cases can be answered. Thus, for instance, when great dykes, such as those that traverse the north of England for miles, change little their composition; and we hear, even at a most recent date, such an authority as Mr. Teall arguing against this theory; it does seem in a tottering state. We must, however, remember that in most cases we are only able to examine a dyke, over any large area, in its horizontal extension; but what is really necessary would be to investigate such sheets of rock in their vertical extension. There are examples in various parts of the world were dykes that extend to some distance show alteration in composition as the rocks traversed change in character.[1] Von Buch and others have shown that in the Tyrol granite veins gradually pass into basalt ones, when traversing dolomitic limestone. The basalts of the Cyclopean Islands that are intrusive in a clay are most markedly altered where the dykes are thinnest. It has been shown that the great Whin-Sill has swallowed up beds roughly equal to its own thickness. On theoretical grounds we could easily understand an acid lava taking up limestone with its impurities, and

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[1] N. S. Shaler. "Propositions concerning the Classification of Lavas, considered with reference to the Circumstances of their Extrusion."—*Anniversary Memoirs of the Boston Society of Natural History*, 1880.

becoming more basic, and thus reducing its temperature whilst it became more fluid. If this were the case we can understand that further action on limestone would be limited by saturation of the magma with lime and its low temperature. It therefore seems that we should look more to granite and its derivative as fuses of limestones than to basic rocks. Why should not the basalts of Mull be the result of the contact of the granites with the underlying limestones? I have brought the subject forward, not with the intention of offering new evidence, but to again direct attention to such an important branch of vulcanological science.

Let us now turn our attention to the mineral composition of an igneous rock. Any given magma will produce rocks of the most varied character, according to the conditions under which consolidation takes place. Thus, for instance, a given dyke of magma might be a granite near its origin, higher up its sides or whole may be pitchstone, and its centre a liparite or porphyry, whilst at the surface it would present itself as vitreous pumice and ash, an obsidian or a quartz trachyte. It has been observed that granite veins branch out, and the ramifications may assume the type of felsite, which is of course dependent on the more rapid cooling, just as in the case of the salband. Again, we have a series of gradations from a true leucitic basalt, such as the recent lavas of Vesuvius to a sanidine porphyry, to a highly crystalline syenite containing leucite, but more commonly nepheline in the rocks, composing the ejected blocks. The generalization based upon the geological ages being characterized by different types of rocks is false, and is no doubt due to the depth to which denudation has extended. It is a general fact that the slower the cooling takes place the more perfect will the cystallization be. This we have already spoken of when treating of the difference in the amount of gaseous constituents in a magma which, by bringing about great rapidity of cooling in explosive eruptions, makes the products tend to an amorphous rather than a crystalline condition. One remarkable fact well borne out by the lavas derived from the different eruptions of Vesuvius is that the size of the crystals are much greater in the little oozing forth of a small quantity of lava from the crater than in the great outpoors. This will be evident, as in the first case the lava has been in a state of simmering in the upper part of the chimney for a long time, and will have been loosing its heat in a very gradual

manner, so that such minerals as leucite and pyroxene at Vesuvius, or the latter mineral at Stromboli, are able to gradually increase in size and perfection, which will proportionally diminish the crystallizability of the remaining vitreous matter. Professor Samuel Haughton[1] has shown that the remaining paste consists of a very fusible basic glass with an approximate composition of 2RO, SiO^2 containing much iron protoxide. On the other hand, a large supply of lava brought up from below with considerable rapidity has little time for the growth of individual crystals, but the whole mass undergoes a microcrystalline change until no, or very little, vitreous matter remains to feed the further increase of individual crystals. We have a parallel in such a case as the following:—If we make a solution of some salt very soluble in boiling water, but very slightly so in cold, and we cause such a solution to cool moderately quickly, the salt will separate itself in a granular crystalline state; but if such cooling be made to take place gradually during many days, very fine, perfect, and large individuals will replace the granular types. Now, when a microcrystallization takes place, it will so separate the remaining vitreous material that even under the microscope little will be discernible, so that it is very difficult to detect it or appreciate its amount. But where suitable conditions favour the growth of large crystals in a similar magma, the vitreous matter that remains will be more concentrated, and therefore more apparent both to the naked eye and under high magnifying powers.

The histological character of any cooled magma, with regard to its mineral components, is a question of profound interest, which, up to the epoch of the attempts of artificial reproduction of different types, aided by microscopical research, remained a very obscure subject. When we have to deal with the fused components of any single mineral in a pure state, the researches of Messrs. Fouqué and Lévy demonstrated that, so far as laboratory experiments go, the critical point of crystallization is near that of the fusing-point of a mineral. We should, therefore, expect that in a leucitic lava, the leucite would be first to separate as crystals, to be followed by felspars, and last by pyroxene. It is a well-known fact that some of these crystallized simultaneously. This

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[1] "Report on the Chemical, Mineralogical, and Microscopical characters of the Lavas of Vesuvius from 1631 to 1868."—*Trans. Roy. Ir. Acad.*, vol. xxvi., p. 141.

is most strikingly illustrated by a coarse leucitic lava exposed near Orchi, on the volcano of Roccamonfina, where leucites, some two or three centimeters in diameter, enclose many large and perfect crystals of sanidine and pyroxene, which, in some cases, are entirely enveloped, or protrude a short distance from their surface. We might, with such a series of contradictions, feel inclined to give up further experiments in the laboratory. Before, however, let us compare what has been done by the chemist, and see if it is borne out by rocks as presented to our observation by nature. We will commence by recalling the interesting researches of Sir James Hall,[1] who noticed that if such igneous rocks as whinstones and basalts were fused and cooled quickly, a glass resulted; but by keeping them near fusion-point (*recuit* of modern French authors), or allowing them to cool slowly, a crystalline structure resulted. These experiments were followed up by Gregory Watt,[2] who went a step farther, and demonstrated that the sp. gr. increased in proportion to the prolongation of cooling.

The absence of microscopical research prevented any important inferences from being drawn from these early experiments, and it was not till the investigations of Daubrée, Hautefeuille, Freidel, Sarasin, Fouqué, Michel Lévy, and others that much advance was made. These authors[3] found that by *recuit*, more or less prolonged, the following minerals might be obtained from their fused chemical components:—Peridote, pyroxene, nepheline, leucite, triclinic felspars, mellilite, gehlenite, and sphene; whilst from mixtures not corresponding to the mineral obtained the following were prepared:—Tridymite, oxides of iron, and perovskite. Many of the first group are obtainable from indefinite mixtures. It is this latter point that is undoubtedly the true key to this enigma of the different results in nature, and in the laboratory.

It will be convenient to take up the principal rock-forming

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[1] "Experiments on Whinstones and Lava, 1798;" and also *Trans. Roy. Soc. Edinb.* 1805, vol. v., pp. 8 and 56.

[2] "Observations on Basalt and the Transition from the Vitreous to the Strong Texture which occurs in the gradual Refrigeration of the Melted Basalt, with some Geological Remarks."—*Phil. Trans.*, 1804, p. 279.

[3] Encycl. Chimique, tome ii., Metalloids. 1er Appendice. Reproduction Artificel des mineraux e roches. L. Bourgeois, p. 10.

minerals one by one and compare their occurrence in nature with their reproduction artificially.

Peridote was obtained,[1] amongst other methods, by *recuit*, at a white-red heat, of the elements of a basalt, exactly identical in all characters with what occurs in nature. This mineral occurs naturally in two forms. The first are irregular nodular masses, found as bombs, or entirely enveloped in the lava. From their large size they must have required a long time to crystallize, which took place in all probability before the extrusion of the magma. They, no doubt, resulted in some cases by actual crystallization from the igneous matter; but, I believe, by far the larger part are nothing more than a very advanced metamorphism of a dolomite; for amongst the ejected blocks of Monte Somma or Roccamonfina we may obtain all gradation between the original sedimentary rocks and these masses of pure olivine. The most common form, in a petrological point of view, is the disseminated grains that often go to make up a rock. These are seen to be nearly always one of the first conversions of the amorphous paste into *formed* material. Yet the actual conditions suitable to its crystallization are not quite clear; for we find lavas ejected from the same volcano abound with it sometimes, and at others it is quite difficult to find. So far as my observations go, it favours the basic rocks of fine-grained structure, and especially those that have cooled quickly from a very high temperature, although it seems capable of increasing in size during slow cooling from a very high temperature, in consequence of the lava stream being very deep. This is the case with some very coarse lavas of Vesuvius, such as that of Pompeii and Cisterna, which contain some crystals a centimeter long.

Amphibole.—This mineral has baffled all the attempts of the chemist to prepare it artificially otherwise than as a sublimation. Whenever its elements were fused separately, or a complex mixture, was fused, the only product was its ally—pyroxene. Our entire acquaintance with amphibole indicates it as a mineral crystallized under pressure, and probably from an aquiferous magma. Its continual occurrence in syenites and allied rocks show it to be easily crystallizable under the conditions which these rocks came

[1] Fouqué and M. Lévy. Bull. Soc. Min. 1881, t. iv., p. 275.

into existence. I have found it in basic pumices continually accompanying orthoclase (of which we shall speak next) in the more vitreous and early stage of the explosive eruption ejectamenta of Vesuvius, Roccamonfina, &c. In the later stages of the same eruption it does not appear to have increased in size or abundance, whilst it is often enveloped in pyroxene; and this latter species is spread throughout the mass, increasing in proportion as the rock approaches the lava type. This is the more remarkable, because we know that amphibole is more fusible than pyroxene; whereas, if we exclude change of pressure, &c., it should have crystallized later. This fact alone is quite sufficient to disprove any relationship between the fusing-point of a mineral and its order of crystallization. Where amphibole is found in a lava, we have evidence that it existed as such before the eruption of that material. It is not at all an uncommon mineral lining vesicular cavities; but it there shows itself to have been deposited by sublimation, which is borne out by its discovery under similar conditions in some furnace scorias.[1]

Orthoclastic felspar was obtained by M. Stanislas Meunier[2] by fusion and subsequent *recuit* of acid rocks. The product, however, only consisted of crystalline concretions, having the composition of orthoclase. Microliths only rewarded the efforts of Messrs. Fouqué and M. Lévy[3] after a long *recuit* of eight days. These facts are thoroughly borne out by the basic pumices. Those that were cooled very rapidly in the first eruptive stage exhibit large, well-formed crystals of sanidine associated with amphibole, showing the similar conditions under which the two minerals were formed.[4] In the latter stage of these eruptions the large crystals have not increased in number or size (?); but from the slower cooling a few microliths have formed. Another proof is to be found in the occurrence of fragments of a porphyritic rock, which is only the pumice magma that, in some outlying fissure, has cooled under pressure, and in some cases undergone secondary alteration. This shows the sanidine crystals still larger

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[1] M. L. Bourgeois, Op. cit., p. 119.

[2] Comptes rendus, 1880, t. xc., p. 1009.

[3] Comptes rendus, 1878, t. lxxxvii., p. 700.

[4] Whether these are really orthoclastic is generally a very difficult matter to determine.

and more perfect. This rock may be traced by gradations to a syenite-like rock, in which the amorphous magma is entirely converted into *formed* matter. In the basic lavas, which are identical in composition with the above pumices, the sanidine only occurs as very small crystals or microliths, as the magma rising quickly to the surface has little time to partially crystallize under pressure. On the contrary, after extrusion, the lava will cool very much slower than the pumice, so that the prolonged *recuit* will be highly favourable to development of orthoclase microliths, and even small crystals. These facts are well borne out by Vesuvius in its pumices and modern lavas, whilst the outflows of *Phase IV.*, following immediately on a pumiceous phase, hold an intermediate place with regard to their monoclinic felspars. It is not an uncommon thing in basic pumices to find sanidine[1] crystals eroded, enclosed in others, which in turn may exhibit eroded surfaces, and again be enclosed in a third crystalline shell with well-defined facets. The orientation of each crystal being different from that which it coats, or is covered by. It is evident, therefore, that this mineral must have undergone a series of vicissitudes which must have taken a far longer time than was occupied in the eruption and cooling of this product of an explosive eruption, and must have required more quietness than could occur in the expansion and ejection of pumice. This latter example I take to be an important argument in favour of the hydro-thermal, or plutonic, formation of orthoclastic felspar in a magma cooling under great pressure. Another fact also of deep interest is the very extensive replacement of sanidine in the Vesuvian pumices of *Phases III.* and *IV.*, by leucite in those of *Phase VII.* and the lavas, as these are the two principal competitors for the potash. If the granite and syenites of the Val di Fassa, and the latter of Skye, described by Scrope and Geikie respectively, are really subaerial expansions, which I doubt, we must suppose them to have been nearly completely crystallized before eruption. Porphyries, no doubt, are erupted granites, which had undergone much crystallization *before their extrusion.* Even in the most vitreous rocks, such as the obsidian and obsidian pumice of Lipari, where the latter, although, as a

[1] H. J. J. L. "Geology of Mt. Somma and Vesuvius," &c. *Q. J. G. S.*, Jan., 1884, p. 71.

whole, a highly vitreous mass, contains large crystals of sanidine scattered through its mass.

Triclinic felspars.—Other felspars, such as labradorite,[1] were produced by a *recuit* of some days; but large crystals, such as are met with in the Etna lavas, do not so far seem to have been obtained. Such a result is easily explicable, when we are informed that to produce a microlith some days are required, whereas we know that even after the expulsion of the lavas of Etna many months or years are requisite for their cooling, so that *recuit* may be prolonged far beyond the limits within which we can experiment. If a large stream of lava, such as issued from Etna in 1669, be examined, it will be found that even that which was cooled immediately contains crystals of labradorite, which indicate the plutonic origin of that mineral, or that the magma had been undergoing a prolonged *recuit* in the upper part of the chimney. Specimens taken from the centre of some of the thicker parts of the stream far from its source, and which must have been long in cooling, we find the crystals of that felspar therein contained have attained greater dimensions, thereby indicating that under favourable circumstances this mineral may undergo further growth after extrusion of the lava. A similar occurrence I have noticed at Vesuvius. At Cisterna is a gigantic lava stream that is known to be more than half a kilometer broad, and its depth beneath is unknown, although it is quarried to a depth of twenty meters, at a distance of more than ten kilometers from the original eruptive axis of the mountain. Now, of all the lavas of Monte Somma this is the most extremely crystalline one, all its constituents being of very large size, and practically all the amorphous paste has passed into a crystalline condition. So far as is known, this is the greatest outpour that ever occurred from this mountain; and, no doubt, in consequence of its enormous thickness, being unrivalled by any modern stream, a very long time must have been occupied in its cooling, conditions highly favourable for the production of a coarse structure. When small streams dribble from the crater after prolonged strombolian action, the structure also is often very coarse, as the part of the lava column in the chimney has been gradually loosing its heat. Anyone who visits Monte

[1] Fouqué and Lévy, Comptes rendus, 1878, t. lxxxvii., p. 700.

Somma may have noticed that most of the lavas along its crest are coarse-grained, whereas most of those near the toe are fine-grained. The reason, as at present with Vesuvius, is obvious.

From the almost impossibility of artificially producing the felspars, Delesse,[1] Daubrée,[2] and Sorby,[3] assert that they must be the result of hydrothermal origin. Whether the actual presence of water is necessary directly, or only as the means of increasing the tension and pressure in the magma, seems at present unanswerable.

Anorthite was the most easily obtained, and corresponded in characters exactly with the same mineral in lavas that have consolidated near the surface. This mineral, as is well known, is rarely met with in true plutonic rocks.

Quartz appears never to have been produced artificially, except from solution in water of silicates of a glass at a high temperature and pressure by Daubrée; and from the abundance of fluid cavities seems to be the result of (in rocks) hydrothermic origin under very great pressure.

Leucite, although a mineral of local occurrence, is of deep interest to the petrologist. It has never been met with amongst furnace slags, except as a sublimation. M. Hautefeuille[4] obtained measurable crystals by fusion of the components of leucite in vanadate of potash. Fouqué and M. Lévy[5] obtained by igneous fusion and *recuit* without a flux. With the components of leucite alone it was impossible to obtain the mineral, and this could only be done by taking equivalent components of a mixture of that mineral and pyroxene. This is a most important fact that again helps to clear away the veil of mystery which overhangs the genesis of many silicates. Most substances can be obtained crystallized by one or more of four principal methods—from sublimation, by fusion, by evaporating a solution, and by cooling down a solvent. The necessary temperature is highest for the first, less for the second, and very much the lowest for the third and fourth. Sulphur, to be obtained in crystals from fusion,

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1 *Bull. Soc. Geol.*, 1857 and 1858, vol. xv., p. 728, 757, 769.

2 Rapport sur les progrès de la geologic experimentale, 1867, pp. 63 and 84.

3 *Brit. Assoc. Reports*, 1880.

4 Annales Scient. de l'Ecole norm. sup. 2nd series, vol. ix., 1880.

5 Comptes rendus, 1878. t. lxxxvii., p. 961.

requires a temperature of at least 115° C., whereas by solution in carbon bisulphide we may obtain crystals far more perfect at the ordinary temperature of the air. We must, therefore, look upon leucite as dissolved in a medium which is liquid at a bright red heat, and only gives up this, as well as other minerals, by a lowering of temperature, in the same way that a mixed boiling saturated solution of salts of various solubilities separate out (far below their fusing-point) as the solvent cools. Precipitation might also depend upon withdrawal from the mixture of one or more of its elements for the formation of a mineral that has already commenced to separate. If we take a solution of mercuric biniodide in a solution of potassic iodide, and add some substance that will seize upon the iodine in the latter salt, such as argentic nitrate, we have an immediate precipitate of the mercuric biniodide proportional to the amount of potassic iodide broken up. Stoppani gives the example of nitrate of potash dissolved in water, which is precipitated immediately if alcohol is added.[1] The fact, therefore, of leucite crystallizing far below its fusion-point proves the solution of that mineral in that glass or some other. This would explain the crystallization of the two minerals simultaneously, as at Roccamonfina; for as the lowering of temperature took place in the magma as the pyroxene crystallized out, the remaining would become supersaturated with leucite, which would have to separate. We might possibly imitate this condition in freezing a saturated solution of a salt in water. It is also possible that the leucite does not form until the potassic chloride in the magma has been broken up, and the HCl has escaped in the vapour.

In the formation of rocks we have a process of fractional exhaustion of the original amorphous medium, in which secondary combinations can hardly be conceived to take place until some portion assumes definite crystalline form, the kind of which will depend upon the elements that enter into the composition of the mixture, and the train of conditions which that undergoes in passing from a higher to a lower temperature. Starting, for example, from an amorphous mass of fused silicates, we may suppose that condition 1 is favourable to the formation of mineral

[1] Corso di Geologia, vol. iii., p. 131.

B, but as this separates, A can no longer remain in solution, so this also separates until the magma is deprived of as much of the elements as these minerals A + B can take up, and the glass is then suitable for the growth of C which comes next, and in its turn may be followed by D, and so on. The resulting rock will be composed of the minerals A + B + C + D, &c. Let us again start with the same magma, and suppose that condition 2 comes into play, which is favourable to the formation of A, which will separate, exhausting the magma to a point that it is suitable to the formation of X, in preference to any other, which now carries the exhaustion on, till the magma approaches Y in composition, which in turn continues the exhaustion, till the unformed material is suitable for the crystallization of D. We should thus obtain a rock containing the minerals A + X + Y + D, both of which would be identical in ultimate chemical composition. Now, condition 1 may have been favourable to rapid expansion, and eruption such as pumice results from, whilst condition 2 we may take to represent the gentle outflow of lava. The reality of this somewhat rough illustration will be more apparent if we compare the vitreous pumices of *Phases III. and VI.* of Monte Somma, in which leucite is absent, and sanidine abundant, with the highly leucitic basalt lavas of the same volcano, in which sanidine at the most is a very unimportant element, remembering at the same time the practically complete identity in chemical composition of the mass of either. An interesting point in connexion with this is the fact that Messrs. Fouqué and M. Lévy obtained a leucitic rock from fusing together orthoclase and biotite. Prof. Samuel Haughton[1] was, I believe, the first to treat the mineralogical composition of a lava on the principle of the exhaustion of the element of the magma or paste, the different minerals competing for certain oxides which are necessary for their formation, so entirely devoting himself, with remarkable ingenuity to the chemical side of the question, but disregarding the physical, which, however, hardly entered into the scope of the subject discussed. We must, however, not forget the varying conditions under which cooling, in an igneous rock, takes place, such as time, pressure, water, volatile acids, and their corresponding salts, which must be most important elements in modify-

[1] Op. cit. pp. 68 and 138.

ing the ultimate mineralogical composition of the solidifying rock. Let us take two groups of the mineral elements of Vesuvian *essential* ejectamenta; we have leucite antagonistic to amphibole, nepheline, and mica, all competing for the potash. Now, in the pumices of the great explosive eruptions of *Phases III. and VI.* we find amphibole, sanidine, and biotite using up the potash, and being the principal crystalline ingredients, whereas in the lavas that cooled under quite different conditions we find these minerals reduced to a minimum, whilst all the potash has been seized upon by the leucite, and sometimes a little nepheline. How can we account for such phenomena, otherwise than in change of conditions? Again, we find pyroxene, antagonistic to olivine, amphibole, and biotite, competing for the magnesia. Again, in the Vesuvian pumices, amphibole and mica prevail, as these had probably formed under great pressure, whilst in the same pumices that escaped more slowly, and in the lavas, it is the pyroxene that monopolized the magnesia. We know that olivine (?), amphibole, and biotite are met with in their greatest perfection in plutonic rocks, whilst pyroxene is remarkably characteristic of rocks slowly cooled near the surface, and under low pressure. The fact of the former of these having resisted all attempts at artificial production points to conditions which have not yet been adopted in the laboratory, whilst leucite and augite are produced with ease and certainty. We therefore must conclude that antagonism of mineral species in crystallizing from a medium depends not only on the composition of that medium, but also of the surrounding physical conditions. Prof. Haughton[1] admits that, according to his theory, olivine ought to prevail, as it has only to contest for iron and magnesia, whilst pyroxene, amphibole, and biotite, are weakened in the additional fight for lime or alumina. He attempts to explain this by a theoretical principle which he calls that of *minimum paste*, which would not have been requisite had the physical conditions been taken into account. Again, this theory in its incomplete form is proved insufficient by the joint author, Prof. E. Hull,[2] in the same memoir, although it was undoubtedly a great step in the direction of an important principle.

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[1] Op. cit.

[2] Op. cit., p. 141.

M. Bourgeois[1] accounts for the crystals of pyroxene in leucite to be the crystallization of the glass cavities. This is obviously not the case, for the following reasons:—In the leucites of Roccamonfina and Vesuvius the crystals of pyroxene entirely traverse, project their ends on each side, whilst the leucite material is accurately moulded on the crystal facets of the pyroxene, which form leucite could not give to a glass space. Besides, many pyroxene crystals bear no relation whatever, either in size or position, to the remaining cavities, which themselves do not show such crystallization. Their crystals are often imbedded in the leucite mass, and project into a glass cavity, the latter portion being no thicker than the former, which was entirely enveloped in the leucite mass. Where much growth of crystals in glass cavities take place, that portion surrounded by the vitreous paste of the glass cavity should have increased in size. That the artificial conditions employed in the laboratory fairly represents the natural ones in the production of leucite there exists little doubt; the variations in temperature were just such as we meet with in the formation of that mineral at Vesuvius. Besides, the two minerals were identical in crystallographic characters, both externally and internally, as seen by polarized light, and also the great resemblance as exhibited in the strata of glass cavities.

That leucite may separate or any rate increase in size, after expulsion of lava, seems to be demonstrated by the observation of Scacchi,[2] that the scoria of the lava of 1855 did not contain large crystals, and that in the lava the distribution of them was irregular, which seems to show that *recuit* at least increased their size.

In describing leucite I have considerably erred from the direct road, led on by the train of argument, based principally on the physical and chemical properties of this interesting mineral.

Biotite, though commonly met with in volcanic rocks, could not be obtained as a distinct form by Messrs. Fouqué and M. Lévy. In lavas we generally meet with this mineral in large, well-formed crystals, as also in pumices. In some basic pumices of Monte Somma (*Phase III.*) very beautiful hexagonal micro-

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[1] Encycl. Chim., vol. ii., Metalloids, I^er Appendice. Reprod. Artif. des Roches, p. 212.

[2] Guarini, Palmieri, Scacchi. Mem. Sul. Incend. Vesuv., 1855, p. 152.

lithic plates, and small crystals may be seen scattered throughout the magma, and often enclose crystals of orthoclase. In the more highly crystalline pumices and lavas this mineral occurs generally as well-formed crystals. Although it is not very uniform in its occurrence, I am disposed to regard it rather as pre-eruptive in formation, or, at any rate, in part.

Magnetite is another mineral that cannot be obtained by simple fusion, but requires solution in a fused medium, from which it separates during cooling within a great range of temperature,[1] provided the formation of other minerals renders the magma supersaturated, from time to time, with this oxide, so that various crops of crystals may result, forming so many *periods of consolidation.* This is the only way we can explain its formation as with quartz, leucite, &c. Scheerer pointed out long ago the granite-forming minerals separated inversely to their fusion-points.

Pyroxene, as well known, is a common product in furnace slags, and is easily obtained by simple fusion of its elements with a very short *recuit.* Messrs. Fouqué and M. Lévy found it to be produced in a microlithic condition after a few moments' *recuit,* and prolonging this a little, fine crystals, such as are met with in volcanic rocks, were obtained. Such a fact convinces us of the extreme rapidity with which basic pumices, at any rate, must have passed from the fluid to the solid condition, as in many of the Italian basic volcanoes the first products of some of their explosive eruptions were practically without even microliths of pyroxene, striking examples of which are to be met with in the deposits of *Phase III.*, period 1, and *Phase VI.*, periods 1 and 3, of Monte Somma. The above-mentioned authors found the limit of temperature rather wide in which this mineral crystallized, which accounts for its inclusion in others that separate at rather higher temperatures. The pyroxenic glass seems to be the principal medium in which the other silicates and oxides are dissolved in basic rocks, whereas an acid felspathic glass seems to perform the same function in acid ones.

We may regard the magma from which results an igneous rock as a variable mixture of acids and bases, as pointed out by

[1] Bull. Soc. Géol. 2e serie, tom. iv. page 478.

Abich. Now, as consolidation takes place, great excesses of either, especially the feebler ones, such as magnetite, are compelled to separate; and as the rock completes its crystallization, the excesses of either form the last crystals, unless the rock suddenly cools before all the vitreous matter has been converted into *formed* material. Thus, in the acid rocks we have quartz, and in the basic ones magnetite, being the last formed minerals, although the two most infusible of rock-forming minerals, which alone is sufficient to demonstrate that fusion-point has little or nothing to do with the order of separation of the minerals. We should therefore be more justified in determining whether a rock should be regarded as acid or basic by its microscopical structure, than by adopting 60 per cent. of silica as rigidly dividing the two, since the different bases vary much in alkalinity, and combining proportions, and a magma containing 60 per cent. of silica, might give an acid or an alkaline reaction, according to the quantities of different bases it contained.

Limit of space prevent further consideration of the different mineral species which go to make up igneous rocks; the above, being most common, are sufficient to indicate the line of argument followed out. Before, however, quitting the subject, there is one more point worthy of our consideration in relation to the separation of mineral species from a solvent. Different species have been easily obtained from fusion of their components in a saline substance, such as a chloride or sulphate. Thus, for instance, M. Lechartier[1] obtained pyroxene in crystals, a centimeter long, by fusion for a couple of hours in calcium chloride, or sodium sulphate. In the same way wollastonite, apatite,[2] and many other minerals have been obtained by E. Belmen as very perfect crystals from solution in fused chlorides, and other salts, such as vanadates. These facts go to confirm what has been said about the solution of the more infusible silicates in the more fusible ones, and at the same time may account for the occurrence of some minerals that are eruptive, or post-eruptive, in time of their formation. The large amount of sulphates, but especially chlorides, that are vapor-

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[1] Comptes rendus, 1868, vol. lxvii., p. 41.

[2] L. Bourgeois, Encycl. Chim., vol. ii., Ier Appendice. Reprod. Artif. des Roches, p. 10.

ized during an eruption is hardly credible until a few facts convince us that such is the case. I have seen fumarole chimneys having in a short time their whole interior glazed by a mixture of chlorides, one to three centimeters thick, and from the intense heat as transparent as an ice covering, which was, without doubt, the result of sublimation, and not decomposition, as the rocks upon which it was deposited were quite unaltered. Another proof of the large amount of saline substances ejected by a volcano is the quantity met with in the falling ashes during a lava eruption. The outburst in 1872 produced an ash asserted by Prof. Palmieri[1] to be poorer in soluble constituents than any other since 1855, yet it contained from 4 to 9 per cent. of saline matter, chiefly sodic chloride. As this eruption was lateral, the principal part of the ash was derived from the crater edges and chimney walls, which would tend to lower the amount of soluble portion.

It was observed in the eruption of 1855[2] that the alkaline chlorides were only evolved sometime after the lava had been cooling—that is to say, saline crusts only formed around the fumaroles at a late date; and I have noticed the same thing. Scacchi supposed that it may be a spontaneous rise in temperature in the lava in cooling, similar to that developed in phosphate of lead, nitrate of copper, or argentic[3] iodide when passing from the amorphous to the crystalline condition. Or again, to their early union with other elements of the lava. This may possibly be so, the combination being broken up by a lowering of temperature (?), leaving the chlorides free to be sublimed. It seems to me that the chlorides must be continually escaping, but that they are not deposited until the scoria and fumarole sides are cooled enough to allow such to occur. The liquids included in cavities in crystals are generally solutions of chlorides or sulphates.

There is little doubt that these saline materials must form a very important constituent of the magma; but whether they play much part as a solvent medium for certain minerals is a thing yet to be experimentally verified, though one is inclined to think that they really do perform a very important function in that way.

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1 Annali del Reale Osserv. Meteor. Vesuviano, 1874, p. 73.

2 Guarini, Palmieri, Scacchi. Mem. s. Incend. Vesuviano del mere di Maggio, 1855, &c., pp. 141, 143, and 149.

3 G. F. Rodwell, *Phil. Trans. R. S.*, Part iii., p. 1134.

One point open to speculation is whether the presence of sodic and potassic chlorides and sulphates is not the determining cause as to whether the magma shall contain leucite haüynite, nosite, or sodalite. For instance, we find Monte Vultura producing at different epochs basalts, leucitic basalts, and haüynite basalts, which might result from the accidental introduction of such salts from the sea or other sources. We might suppose that the salts are decomposed and dispersed as acids, whilst the bases are seized upon by the silicic acid which, in a magma at high temperature, has powerful acid properties, and so forms minerals of the leucite or felspar groups.

In this Paper I have brought together a considerable number of observations, and endeavoured to glean from them the clue to some of the most important problems of geological science. The train of argument is somewhat disorderly; but from the large number of circumstances that enter into the question of the formation of igneous rocks, the subject is difficult of arrangement. It is unmistakably evident that if the young science of petrology is intended to be carried beyond the simple dry description of rock masses, it must be brought to bear upon the various modifications and derivatives of them, in any given district, and also that it will never supersede field investigation ; but by the two going hand-in-hand they may open the doors and show us the secrets of Nature's great chemical laboratory—our globe.

XVIII.—ON THE PERMANENCY OF FROST-MARKS, AND A POSSIBLE CONNEXION THEREWITH WITH OLDHAMIA RADIATA AND O. ANTIQUA. By J. JOLY, B.E., Assistant to the Professor of Engineering, Trinity College, Dublin.

[Read, March 24, 1886.]

The object of this note is more to draw attention to a line of inquiry, possibly not unfruitful, than, with the present amount of evidence, to demonstrate any hypotheses. The experiments necessary to throw light on the hypothesis suggested demand more time than I will for many months be able to spare. Some few experiments have, indeed, been made, and, for more than a year seeking for leisure to continue them, I have postponed bringing the very simple matter before the Society.

In the Christmas holidays of 1884, I, in company with some friends, was engaged on a short excursion through the Co. Wicklow. The weather was frosty, freezing at night, and thawing by day in the sunshine. There had been rain, and the roads, where the thaw prevailed, were soft and muddy. In this mud, just outside Roundwood, we noticed very regular marks, evidently left by the frost. The frost was gone, and the mud was soft and wet; but in ruts and empty pools, wherever a smooth surface obtained, the frost had channelled its impress. The appearance was that of tufts, regularly radiating from a centre in rays which straggled over the slime in long tendrils, these being again often subdivided into more numerous tendrils. The effect produced so closely resembled the tufted appearance of *Oldhamia radiata*, that the thought was immediately suggested of the possible common origin of the two, and I drew the attention of my companions to the resemblance, which one of them, Mr. Crosthwaite, was well able to appreciate, being familiar with the Oldhamia marks.

Similar marks were subsequently met with in abundance that day, and again noticed in Glendassan the ensuing day. I have since observed them after every frost.

How the marks are caused, it is not hard to understand. If a surface consisting of loose small particles, holding water in the interstices, be exposed to a low temperature, certain of the more prominent particles, exposing a capillary surface of water more freely than their neighbours, become centres of crystallization, from which crystallogenesis is propagated, the molecular forces at work being sufficient to disturb the loose sand particles, so that they shall take up a position accommodating to the form and direction taken by the ice spicules. These spicules, or rays, would, if forming freely, extend, indeed, ever as straight lines; but here, hampered by the jamming or fixity of occasional particles, they wander minutely, now diverted a little in one direction, and again in another, so that the sharp definition of crystalline shape becomes modified into a straggling growth, resembling the radiate straggling of *Oldhamia radiata.*

There is another conspicuous variety of Oldhamia, known as *Oldhamia antiqua.* I traced, indeed, some marks remotely resembling this; but, although we might *a priori* expect such a form to occur, I have not succeeded in finding anything fairly resembling it since, nor have I, in the few experiments made, succeeded in reproducing it. These experiments consisted in washing out the finer constituents of some earth, and exposing this, while saturated with water, to frost. I also froze a slab artificially, by placing immediately above it, in a well-padded box, a metal tray containing a freezing mixture: freezing was produced by radiation from the surface of the mud to the bottom of the tray, which was coated with lamp-black. In this way, it was hoped, the conditions obtaining in nature would be preserved. In general, marks more or less resembling the *Oldhamia radiata*[1] were easily obtained, but the *Oldhamia antiqua* could hardly be said to be reproduced. I said that we might expect a different result. This will appear if we consider the simple arrangement of such marking—a zigzag of nearly straight lines, with tufts at the bends or meeting-points. How such an arrangement might occur in the case of fine sand, interspersed with larger particles, is quite conceivable. Finally, anyone who has observed closely the symmetrical forms of frost

[1] This is by far the more common variety.

on smooth surfaces will not think it improbable that on the surface of fine sand we should find it simulating organic form.

My failure in obtaining the *O. antiqua* artificially may have been due to the texture of sand employed, to its degree of saturation, or, possibly, to the nature of the matter dissolved in the water. Thus, it might not be amiss to try experiments on the freezing of sea-water in mud or fine sand; and a sand made of the silurian slate itself, crushed to dust, commends itself, perhaps, as going towards realizing past conditions.

The subsequent preservation of these marks in the mud during thawing and drying may be perfect, and conditions necessary for their continued preservation, as rock-marks are no harder to conceive than the conditions which have preserved to us the rain-marks so perfectly that we can pronounce, it is said, on the direction of the wind prevailing during the shower.

We have only to suppose alternations of high and low water—the silt-laden water creeping very quietly over mud flats which, frozen during exposure, were again thawed and dried before the incoming water deposited a fresh covering.

It is noteworthy that the grosser spicules appearing on the surface of frozen mud leave, so far as I have observed, no impress. They are, in fact, formed merely in surface-water.

It was hoped at first that evidence might be obtained from a comparison of the angles made by the bifurcating branches of the frost-marks with the angles easily measurable on the silurian slate. But as the crystallographic directions were found to be completely disguised in the first case, the comparison was futile.

In bringing these observations to the notice of the Society, I hope it will be understood that I no more than venture a suggestion, worthy, it is thought, of further elucidation, and not to be lightly dismissed. Even if, on further consideration, it be deemed improbable, it is perhaps not without interest, and, possibly, not without important bearings in other directions to point out that the fragile and beautiful frost flowers, fleeting as they are, can leave an impress of a nature *capable* of being preserved through an eternity of time.

XIX.—NOTE ON LACKMOID AND LITMIN. By W. N. HARTLEY, F.R.S.

[Read, March 24, 1886.]

Last year Mr. H. N. Draper introduced to the notice of the Physical Science Section of the Royal Dublin Society a new substance called lackmoid, which appeared to have the same, or very similar, properties to litmus. He kindly forwarded to me small specimens of lackmoid and litmin. The following notes show, first, that these are different substances; secondly, that they may be of a similar constitution; but we have no decided evidence.

Lackmoid.—0·01 gram. was dissolved in 20 cubic centimetres of alcohol, of 0·8 sp. gr., and mixed with 20 cubic centimetres of water. The substance is soluble in strong alcohol, but insoluble in water. Soluble in alcohol of 50 per cent. by volume. It retained its colour with but slight alteration for several months, the sole change being the acquirement of a blue tinge. This may be due to the alkalinity of the glass of the bottle in which it has been preserved.

Litmin.—0·01 gram. dissolved in 20 cubic centimetres of water and 20 cubic centimetres of alcohol, of 0·8 sp. gr. added. This substance is insoluble in strong alcohol, but soluble in alcohol of 50 per cent., and in water. The solution has become bleached by keeping, notwithstanding that the bottle has been carefully stoppered and not exposed to bright light.

The spectra photographed for each solution after dilution were not remarkable; the actinic absorption of the two substances being much the same, even after the addition of acid. Lackmoid has the more intense absorptive power in the visible spectrum; in solution it is undoubtedly a better reagent than litmus. The alcoholic solution may be added to water and used precisely as a litmus infusion.

XX.—ON THE LIMITS TO THE VELOCITY OF MOTION OF THE WORKING PARTS OF ENGINES. By GEO. FRAS. FITZGERALD, F.T.C.D., F.R.S.

[Read, March 24, 1886.]

Engines are used for transforming one kind of energy into another.

Mechanical engines are of two great classes—ones that transform potential or statical energy into work, and those that transform kinetic energy into work.

Slow-moving overshot waterwheels may be taken as types of the first class, and windmills as types of the second class. In all cases, it is of course possible by mechanical contrivances, such as levers, pulleys, wheels, &c., to obtain any velocity of moving parts; but the velocity I am calling attention to is the velocity of the parts that move with the working substance. Now, in the case of waterwheels it is evident that when the wheel turns so fast that the water in the buckets is descending as fast as it would fall freely, there can be no work being done by the water on the wheel, and so this limits the rate of working of the wheel. It is to be remarked that in the limiting case the efficiency is zero, while the power is zero when the efficiency is a maximum, i. e. when the wheel is turning most slowly, and that there is a rate of working intermediate between these for which the power is a maximum. In the case of windmills, when the sails turn so fast that the wind blows on unstopped, there is similarly no work being done, and, just as in the other case, this limits their velocity.

Heat engines are of a different class, as they are for the transformation of irregular into regular motion; but their mechanical, as distinct from their thermal, arrangements may be grouped as in the last case. Ordinary steam engines work by means of the energy in the steam doing work by pressing on a piston, and evidently this piston cannot move faster than the steam can follow it up. Professor Osborne Reynolds has in the

March number of the *Philosophical Magazine* this year, called attention to the way in which the velocity of flow of a gas into a vacuum is limited, and this limits the velocity of motion of the piston in an engine. He has, however, omitted to notice that there is a greater velocity than the velocity of sound with which a gas can move into a vacuum, namely, at the rate at which its particles are moving. This only comes into effect when the space is so small compared with the free path that we cannot deal with the molecules, as making an indefinite number of encounters on their way across the vessel. In the case, for instance, of a piston in a vessel full of a gas moving suddenly from rest, with a velocity equal to that of the average velocity of the molecules of the gas, which is greater than the velocity of sound in the gas, it is evident that all the molecules that were just on the point of striking the piston would follow it up, and that those that happened to be moving normally to it would keep following it up, and so would be diffusing into this vacuum, at a greater rate than the velocity of sound in the gas. This leads to a diffusion velocity of energy in a vacuum small compared with the free path, quite different from the velocity of sound, and upon which evidently radiometer action depend. It is this that would ultimately limit the rate at which the piston could be moved by the gas. I have explained this at my lectures on the Theory of Steam Engines for some years back. Steam may also be used kinetically, as in Giffard's injector, and Hero's engine; and in these cases velocity of motion is limited by the velocity of flow of the steam.

In the case of most of these engines that transform kinetic energy into work, it is to be remarked that when moving slowly there is a very small power produced at the expense of a great expenditure. For example, in Hero's engine and engines of this type, if the steam runs out freely without moving the engine, there is certainly the maximum pressure tending to move the parts, but no power is produced, even though a great deal of steam is being employed. It is not the same with pressure engines, like ordinary steam engines. They may be worked slowly, and the power produced is proportional to the steam employed. The same distinction holds in the case of water engines working pistons and turbines. In the case of the kinetic

engine we must work rapidly if we are to get a good efficiency, for the efficiency vanishes at the slow limiting velocity. In the case of statical engines, the efficiency is a maximum when they are working at their slow-limiting velocity, and vanishes when working at their quick-limiting velocity. In the case of a perfect turbine, the efficiency is a maximum when going at its quick-limiting velocity. In the case of water engines there is evidently a limiting velocity also depending on the rate of propagation of energy by the water, i. e. its rate of propagating sound. Gas engines have similarly a limiting rate of working, depending on the rate of explosion, i. e. of propagation of energy by the working substance.

Capillary engines and muscles have probably limits of rates of working analogous to those depending on the rates of diffusion of the molecules of the working substances at the working surfaces. We know that muscles like kinetic engines have a zero efficiency when working at their zero limit of velocity, and there is almost certainly a maximum limit to their rate of working. Capillary engines, like M. Lippmann's, are evidently limited by the rate of diffusion of the molecules at the capillary surfaces, i. e. of the superficial energy.

Electric engines have got analogous properties. There are the two classes—electro-static engines, such as a reversed Holtz machine, and electro-kinetic engines, such as ordinary magnetos and dynamos. The former can be worked as slowly as we please, without waste of energy; but the latter require to be worked at near their limiting velocity to have a good efficiency. A limiting velocity in the case of dynamos is well known, and is attained when the inverse electro-motive force of the dynamo is equal to the driving electro-motive force; but with a given electro-motive force it does not seem at first sight as if there were any limit to the rate of working of a Holtz machine or any electro-static engine.

If we, however, consider the electro-magnetic action of moving electricity, it becomes evident that the forces between the different parts of an electro-static engine must diminish as its velocity of motion increases, until its parts have a relative motion equal to the velocity of light, when there will be no more forces between them. If it move faster than this it will become an electro-magnetic

engine, for the electro-magnetic forces will become greater than the electro-static. The way in which this acts is as follows :—Suppose a charged body, e.g. the carrier in any of the multiplier forms of electro-static engines, move near a conductor, it induces on this latter an electric charge which moves along with the moving carrier. I must neglect the resistance of the conductors, because it being of the nature of friction in ordinary engines limits the velocity in quite a different way from the ways I am considering. Now, if the carrier move with the velocity of light, it and its induced charges will have no action on one another, and so there will be no forces tending to move the carrier. Similarly, if a plate with a charge on it move parallel to a conducting-plate, the moving electrification while its velocity is increasing induces a current in the conducting-plate which is permanent, because the conducting-plate is supposed to be a perfect conductor, and the electro-magnetic action of these two, when the moving-plate moves with the velocity of light, is equal and opposite to their electro-static attraction. Thus it appears that the velocity of light is a limiting velocity to the rate of motion of these engines, just as the velocity of the particles of steam is a limit to the rate of motion of the piston in a steam engine. There is the same limit to the rate of working of electro-magnetic engines. Consider a very simple case. Suppose a wire sliding on two parallel rails with a magnetic force at right angles to their plane, and an electro-motive force driving a current round the circuit. If the magnetic force be feeble enough there seems at first sight no limit to the ultimate velocity of motion of the wire. If we consider, however, what takes place when the electricity goes across from the rails to the moving wire, we see that the reason it goes across is because an electrification on the rails induces a charge on the moving wire, and these attract one another and combine, this action being kept going constantly by the fresh charges supplied by the battery. Now if the wire move with the velocity of light, there will be no longer any action between these charges, and so the wire will act practically as a non-conductor. A conductor moving with the velocity of light acts in other respects as a non-conductor, for it is evident that we can have any desired distribution of electricity in it or on it without any tendency for it to change. It would be more correct to describe it as a region in which the electro-static inductive capacity was infinite, and where, consequently, a given

charge produced no force in its neighbourhood. There is another way of looking at this question, and one that leads to another view of the reason for this limiting velocity. It depends on the theory put forward by Professor Poynting that the energy given out at any point in an electric circuit is transferred there through the ether, and as energy is transferred through the ether with the velocity of light, it cannot keep up with a moving body that moves with a greater velocity than this. This completes the very remarkable analogy between the way in which the rate of motion of a piston by a gas is limited by the rate of propagation of energy in the gas, and the rate of motion of electric engines is limited by the rate of propagation of energy in the ether.

XXI.—ON THE OCCURRENCE OF HARMOTOME AT GLENDALOUGH, CO. WICKLOW. By J. JOLY, B.E., Assistant to the Professor of Civil Engineering, Trinity College, Dublin.

[Read, April 21, 1886.]

As I can find no previous mention of the occurrence of harmotome, or indeed of any member of the zeolite family of minerals, in Co. Wicklow, it may not be amiss to call attention to its presence. I have the more excuse for writing a note on the occurrence of this one mineral, as, since the work of Daubrè, a special geological and mineralogical interest is attached to the beautiful group of which it is a member.[1]

The harmotome of Glendalough occurs in the out-put from the Luganure lode, which traverses the granite close to its junction with the schist, and extends into the vale of Glendasan. Much of the gangue has been thrown out at the upper end of the lake, and from this *debris* I took, some few years ago, a very small specimen of the zeolite—so small that I could not be assured of its identity as harmotome till I was so fortunate recently as to find another and larger specimen. The out-put otherwise indicates hydro-thermal action in the lamellar deposits of quartz and calcite. Here also may be found fluorite, sphalerite, barite, strontianite, galenite, pyrite, siderite, chalcopyrite, manganocalcite, and some decomposition products. Specimens of hexagonal calcite, sometimes found here implanted in solitary whiteness on ice-like drusy quartz, are very beautiful.

The zeolite, in both the specimens found, occurs implanted on a quartz matrix, and in one case the little crystals curved over a crystal of sphalerite. The largest of these harmotome crystals is not quite one centimetre in length. They present principally a

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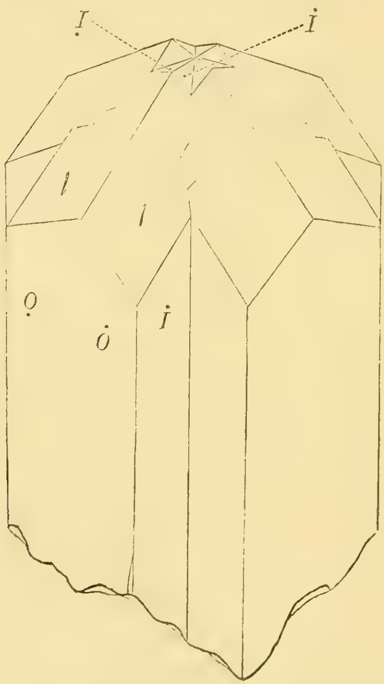
[1] Formation Contemporaine des Zeólithes. The zeolites observed by Daubrè were *engendered* in the matrix rather than deposited. I think it evident that the Glendalough zeolite was deposited. Daubrè's *harmotome* or *christianite*, however, is the lime-potash zeolite *philipsite* of Dana, and is quite distinct from the harmotome described above, which is the barium zeolite.

characteristic cruciform twinning ; but a more obscure lamellar form, of the same mineral probably, is intermingled with the larger crystals. These larger crystals have a high vitreous lustre, and are white, translucent, transparent. The lamellar forms are duller in lustre and are white, nearly opaque.

Crystallographic character.—The accompanying figure, in iso-



metric projection, shows the nature of their crystallographic appearance. It differs somewhat from that ascribed to harmotome by Dana, Des Cloizeaux, &c., due to the conspicuous development of the hemihedral form 1 (copying the notation of Dana), while still preserving the holohedrism of the prism İ. It will be seen that this development has reduced one set of the prism faces to minute dimensions. Indeed they can hardly be seen on the specimen without the use of a lens. In any other specimens I have examined the prism is either predominant—1 having the appearance of a mere bevelling of the edge Oİ, or otherwise, it is eliminated altogether, İ becoming a hemihedral form. The effect is that the

crystal looks as if terminated with four smooth planes, and only on very close examination is it apparent that the pyramid is truncated and replaced by the four prismatic faces. Many of the crystals are terminated thus at both ends.

Working with a defective goniometer, the following values were obtained:—

$$O \wedge \dot{I} = 90°;$$

$$\dot{I} \wedge \dot{I} = 124° \, 20', \text{ mean of nine observations;}$$

$$\dot{I} \wedge \underset{\cdot}{I} = 110° \, 20', \text{ mean of four observations.}$$

Dana records harmotome as orthorhombic, and

$$\dot{I} \wedge \dot{I} = 124° \, 47';$$

$$\dot{I} \wedge \underset{\cdot}{I} = 110° \, 26'.$$

Thus the measurements are evidently sufficiently in accord with a right rhombic prism of 124° 47′. Further, the angle $\dot{I} \, \underset{\cdot}{I}$ agrees satisfactorily with the recorded value. Observations with the polariscope confirms the crystallographic characters ascribed to these faces, but, owing to the generally imperfect translucency of the crystals, are not very definite.

Specific gravity.—I mentioned opaque, white, lamellar forms. To these optical or crystallographic investigation could not be extended. Thinking they might be a distinct zeolite, it was thought advisable to compare their sp. gr. with that of the other implanted crystals. Otherwise, also, it was evidently advisable to determine the sp. gr. of both forms.

In a diffusion zone above Thulet's solution, according to Professor Sollas' method, a fragment of authentic harmotome was placed. On putting in, now, fragments of both the Glendalough forms, they were found to float exactly in the same horizon with the authentic harmotome. Orthoclase of a sp. gr. 2·51 floated below them, analcite floated much above them, stilbite higher still. By calculation, then, a sp. gr. of 2·46 (Dana 2·44–2·45) was ascribed to the Glendalough harmotome. This is a very distinctive test, as the only other members of the zeolite family with so high a sp. gr. are the monoclinic varieties, scolocite and brewsterite.

Fusibility.—Compared with authentic harmotome on the meldometer it was found that the fusion of both occurred simultaneously at a very high temperature. The specimens also blanched below a red heat. It was interesting to compare this behaviour with that of some other zeolites. The result is the following order of fusibility with increase of temperature :—

Chabasite, Stilbite, Heulandite } almost simultaneously.
Natrolite
(*Orthoclase*)
Harmotome.

Harmotome is, in fact, separated from the others by a wide interval. Orthoclase fuses in this interval, and, indeed, decomposition or ebullition of the orthoclase takes place before the melting-point of harmotome is reached. Recent experiments gave me for the melting-point of orthoclase the temperature of 865° C. It is likely that the fusion of harmotome does not occur under 900° C. I had not time to go through with the measurement independently. I would point out, however, that there is very little liability to error in comparing the fusibilities of two substances, placed thus under exactly the same conditions and observed simultaneously in the field of the microscope. On the other hand, not only is the blowpipe a powerful chemical agent, and thus obscures the phenomena of fusion with secondary effects, but with it it is impossible to be sure of fair comparison. The meldometer has shown me that the order of Van Kobel's scale is incorrect. Thus the order it assumes for the fusibilities, almandine, green actinolite, orthoclase, should be orthoclase, green actinolite, almandine; and it is, I think, allowable to assume that similar misleading phenomena account for the fusibility of harmotome being recorded as 3·5 on the scale of Van Kobel. The test of fusibility, like that of sp. gr., is thus a distinctive one in the case of harmotome.

A test of its *hardness* showed that it scratches fluorite, and is scratched by apatite; hardness, therefore, 4·5. In the *blowpipe* it fuses without intumescence.

It does not gelatinize with, but is decomposed by, hydrochloric acid. These tests confirm its identity with harmotome.

XXII.—ON THE TEMPERATURE AT VARIOUS DEPTHS IN LOUGH DERG AFTER SUNNY WEATHER. By GEO. F. FITZGERALD, F.T.C.D., F.R.S.

[Read, April 21, 1886.]

The measurements upon which this Paper is founded were made by me in the month of July, 1876, and I would have hardly thought them worth recording only that I have lately seen it noticed as a new fact that the isothermal surfaces in the Lake of Geneva are not level surfaces; and that this was so in Lough Derg was one of the special features I remarked in my observations of nearly ten years ago.

I made experiments with a maximum and minimum thermometer, attached to a sounding-line, and the differences of temperature observed were so great that there could be no doubt, even with rough experiments.

The observations were made after a long continuance of hot, sunny weather, during which the day temperatures ranged from 73° F. to 75° F., and the night temperatures from 55° F. to 65° F.

The temperature of the surface of the lake rose rapidly during sunshine, at a rate of nearly a degree per hour. In the deep water the temperature of the surface did not rise so fast as in the shallow water. About 3·30 in the day the temperature of the surface water in the deep parts was 71° F., and in the shallows 75° F. From a calculation of the amount of heat that enters the water, it seems that only about $\frac{1}{50}$th, or less, was used in heating it, the rest being probably spent in evaporation. During the evening the temperature of the surface fell slowly, until in the morning it was uniform, to a depth of about five yards, this being the depth, apparently, that the convexion currents during the night reached. This temperature was, on the night I observed it, eleven degrees above the night temperature of a thermometer exposed on grass. In the shallow water the temperature fell more rapidly until it was about 2° colder than the surface water in deep parts, and nearly the same as that of the water at the bottom of

the deep parts of the lake. It thus appears that the cold water supply for the bottom of the lake may be kept up by the cold night water from the shallows.

On laying out a series of afternoon isothermal lines, it appears that they are closer together in the shallow water than in the deep water, the bottom in the shallower water being in general colder than at the same depth in deep water, though, of course, in the very shallow water, where the surface was several degrees hotter than elsewhere, the whole of this very shallow water was warmed up, and was hotter than water at the same level elsewhere. The rate of change of temperature downwards was very regular, from a depth of from five to six yards, to the bottom. At the depth of five to six yards, it changed more rapidly, and from that up to the surface was the region that was affected by the diurnal changes of temperature. During the day the upper layers in this region became much hotter, and during the night the whole of this region gradually became of the same temperature throughout. The depth of this region was observable, during the days I observed it, by the variation in the rate of change of temperature that occurred at this depth; the change of temperature was more rapid here than in either the subjacent or in the immediately superincumbent layers.

From the rate of decrease of temperature in the superficial layers I calculated that the coefficient of absorption of heat per yard was ·71, but as it is known that this is very different, for different rays of the spectrum, it is probable that the coefficient of absorption of the first layers is very much greater. I had not any sufficiently accurate method of measuring the temperatures at near points to determine the rate of change of temperatures for small distances near the surface, but it was certainly very much more rapid than even at a short distance below the surface.

XXIII.—A THERMO-ELECTRIC CURRENT IN SINGLE CONDUCTORS. By FRED. T. TROUTON, B.A.

[Read, March 24, 1886.]

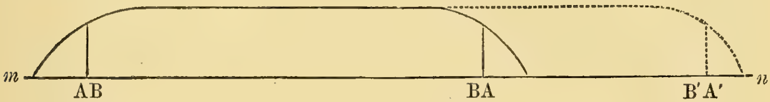
If a flame be placed under an iron wire in circuit with a galvanometer, and be so moved along the wire that the part in the flame is always white-hot, a current is indicated which flows in the direction the flame is carried. The electromotive force is generally in the fourth decimal place. In looking for an explanation of this, it was observed that in front of the flame the fall in the temperature along the wire is more rapid or steeper than behind it. So that, if a difference in the rate of transference of heat in opposite directions in a wire causes a current, as some have supposed, there would be one in this case. The rate of flow of heat is greatest in the direction the flame is moved, for the fall in temperature along the wire is most rapid in that direction. The current, then, and the greatest flow of heat are in the same direction. The amount of the current would thus obviously depend on the difference of the gradients in temperature in either direction along the wire. By making the gradient in front as steep as possible, and that behind the flame more gradual, we should expect an increase in the current. Or again, by making the gradient behind the flame steeper, by cooling it more rapidly than the air can, say by applying water, we should get a decrease in the current, and even a reversal if the gradient became steeper than in front. It was with no small surprise, then, that the opposite was observed on trying the experiment. For, cooling with water behind the flame as it moved along was found to increase the current. That this could not be due to chemical action was ascertained by applying various substances to cool the wire. Thus, whether bodies of a reducing or oxydizing nature were employed the result was always the same.

In order to simplify matters by observing the current when only one side of the flame changed, a row of burners were so arranged that one after the other could be lighted beneath the wire. The current, on turning on the burners in succession, was in the direction that the ignition travelled, or to the side of the steepest gradient in temperature. On turning the burners out in reverse order, one after the other, the current now flowed in the opposite direction to that indicated in the first instance. And it was increased when the cooling was hastened by applying water. The steep gradient is, in both cases, on the same side; that is, both while the flame is spreading out, and again while it is going back. Yet the currents are in opposite directions. However, though the steep gradients are on the same side, it is to be remarked that everything is not in the same condition in both cases; for in one the temperature is everywhere rising, while in the other, that is as the flame goes back, the temperature is everywhere falling. So that it would be insufficient to consider the electromotive force $\varepsilon = \phi\left(\frac{d\theta}{dx}\right)$, but must rather be $\varepsilon = \phi\left(\frac{d\theta}{dx}, \frac{d\theta}{dt}\right)$, θ being the temperature at any point at a distance x along the wire from a fixed point, and t denoting the time.

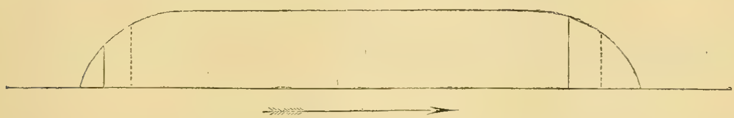
Direct experiments were made to determine if a difference in the flow of heat in opposite directions in a wire was sufficient alone to produce a current. Thus, along a wire on one side of a heated place a moist thread was laid and kept moistened. On coming to a permanent state no appreciable current was observed, though there must be a very great difference in the rate of flow of heat to either side, due to the great difference in the temperature gradients. I find a similar experiment was made by Le Roux,[1] who came also to the conclusion that no current whatever was produced by a difference in the flow of heat in opposite directions in a wire. In another experiment no current was observed in a wire kept heated at the place where it came up out of a vessel of water. So that there can be no term in $\varepsilon = \phi\left(\frac{d\theta}{dx}, \frac{d\theta}{dt}\right)$ containing $\frac{d\theta}{dx}$ alone; but it probably consists principally of $\frac{d^2\theta}{dx}\,dt$.

[1] *Annales de Chemie et de Physique,* quatrième séries, tome x., p. 208.

We may picture what occurs when the high temperature spreads out along the wire somewhat as follows:—When the temperature of a portion is raised to a bright heat, let us suppose the structure to be altered, and with it the electrical potential. Let mn represent the wire, and the ordinates of the curve the temperature at each point. Then, for simplicity, let us for the moment suppose that the difference from the altered part to the unaltered is sudden in the



wire and not gradual. Say, at AB and again at BA, so that from A to B there is a difference in the potential, and again of the same amount, but in the opposite sense at AB. Now, if the temperature spread out on one side, as represented by the dotted line, the junction BA will go out to $B'A'$. However, if we suppose the high temperature to travel out faster than the junction, while the junction is behind its final position, it is at a higher temperature than the junction at AB; and there will be a current, flowing from m to n, if the potential of the centre part was originally higher than the rest of the wire. The reverse occurs when the high temperature goes back. The junction follows slower and is at a lower temperature than AB until it arrives at the final position. The fall in the potential is meanwhile less than at AB. So the current in this case flows from n to m. Now, if we suppose a great number of these junctions beginning with the unaltered wire, and ending with the completely altered, each will have its own normal temperature and can act just as described above in the case of one. By supposing a sufficient number of these we have at length a continuous alteration in the structure of the wire, which is what probably takes place.



In the case of the moving flame the junction in front is at a higher, and the one behind at a lower temperature, than the tem-

perature when at rest, which is shown on either side in the figure by the dotted lines of equal length. The arrow shows the direction the flame is moving.

If water be applied to one side of a heated part of the wire, there is a very rapid cooling and a current flows, due to the higher temperature on the other side, until the junction slowly travels in to the point at the normal temperature, when the current ceases, as was described above.[1] Again, on stopping the water, the current flows for a while in the opposite direction.

So far it has been assumed that the iron, as the flame moves on, cools and returns to its original state; but it does not do so completely. However, if the flame be passed several times over the same part, the iron seems after that to undergo no further alteration. There is a permanent heterogeneousness or alteration found from the place where the heating by the flame began to where it ended, similar to that between the wire and another metal. Either of the ends of this gives a current on heating. In some cases, especially in steel, the currents were easily observed, even at 100° C. The current, as in the case of the temporary alteration in the wire, flows from the altered to the unaltered metal at the hot junction. It follows from this, that the first time the flame is moved along the wire the current is somewhat greater than subsequently, it being the sum of both effects; though afterwards it appears not to alter sensibly in amount on repeated heatings. That currents due to permanent alteration in the structure of metals could be obtained, was long ago shown by Magnus.

Of other metals examined, nickel acts like iron; copper, silver, and platinum appear not to—that is, an alteration once made in their structure remains on cooling; while iron and nickel return partly to their original state. This difference may be owing to the more or less pasty condition iron and nickel assume at temperatures considerably below their melting points; and, probably, both copper and silver raised to temperatures just beneath their melting points would behave like iron or nickel. The difficulty of

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[1] *That Le Roux did not observe these currents may be due to his not employing as high a temperature.*

doing this is considerable, especially in silver, for long below its melting-point it appears to lose tenacity almost completely. Platinum was examined at temperatures approaching its melting point with the oxyhydrogen flame; but the currents obtained were very small, and were due to irregularities in the structure of the wire. As the flame was being carried along in one direction the needle kept to one side or the other, according to the part of the wire the flame was at. A thin rod of carbon examined in the oxihydrogen flame gave a small but regular current as the flame was moved along when water was applied to cool the carbon behind the flame; without this the carbon does not cool quickly enough to give a current.

A difference in the potential along a wire of the nature supposed above, that is due to a temporary change in structure from temperature, could not be discovered by means of a galvanometer, owing to the symmetry on either side, except the temperature alter more rapidly than the structure. For otherwise it would always be equivalent to introducing another metal, and keeping the two junctions at the same temperature.

To state shortly the conclusions finally arrived at, there is, first, a permanent alteration effected in the structure of a wire when it has been once heated. So that, if one of the points between the altered and unaltered metal be warmer than the other, a current flows similar to what would happen if a second metal were introduced into the circuit instead of the altered part. Secondly, that there is, at least in some metals, a temporary alteration of a somewhat similar nature to the permanent one, which lasts while the wire is at a high temperature; and that it is possible to obtain currents from this, is solely due to the fact that, both in appearing and in disappearing, the alteration may take place more slowly than a change in temperature, which ultimately effects the alteration.

What this alteration is, whether stresses similar to what Sir William Thomson found could produce thermo-electric heterogeneousness in a single metal, or whether of the nature of molecular rearrangement of the nature of annealing, may be doubtful.

A better knowledge of the circumstances under which currents can be obtained in one metal may, perhaps, yet afford ground for some molecular theory of thermo-electric currents, the conditions to be considered being reduced in having only one substance in different states to deal with.

XXIV.—PRELIMINARY ACCOUNT OF THE TETRACTINELLID SPONGES DREDGED BY H.M.S. *CHALLENGER*, 1872–76. By PROFESSOR W. J. SOLLAS, LL.D., D. Sc. Part I.—The Choristida.

[Presented, July 15, 1886.]

The following short abstract of my forthcoming Report on the *Challenger* Tetractinellid Sponges is published by kind permission of Dr. John Murray, Director of the *Challenger* Expedition Reports :—

Tribe I.—TETRACTINELLIDA, Marshall.

Skeleton characterized by quadri-radiate spicules, or "Lithistid" sclerites.

Order I. Choristida, Sollas.—Quadri-radiate spicules are present, but not "Lithistid" sclerites.

Order II. Lithistida, Zittel.—The chief skeleton consists of "Lithistid" sclerites articulated to form a consistent network. Quadri-radiate spicules may be present or not.

Order 1. Choristida.

Sub-order 1. Tetradina.—The chief spicules of the choanosome are tetrads, amphitetrads, candelabra, or modified triana.

Sub-order 2. Trianina.—The heads of the adult trianine spicules are confined to the ectosome.

Sub-order 1. Tetradina.

Family 1. **PLAKINIDÆ.**—The canal system is eurypylous. Candelabra are present.

Family 2. **PACHASTRELLIDÆ.**—The canal system is either eurypylous or aphodal. The tetrads are simple.

Family 3. **CORTICIDÆ.**—The canal system is aphodal; the characteristic tetrads are candelabra, or forks with trifurcate arms, or forks with the surface ornamented by spines, or amphitetrads.

Sub-order 2. Trianina.

Family 1. **TETILLIDÆ.**—Flesh spicules are arculi or spirulæ; the triana are characteristic; the canal system in the lowest forms is eurypylous, in the highest, aphodal; the ectosome in the lower forms is the outer epithelium and a thin layer of collenchyme; in the higher, a highly differentiated cortex; choanosome, a collenchymatous mesoderm in the lower forms, sarcenchymatous in the higher.

Family 2. **THENEIDÆ.**—The flesh spicule is a spini-spirula; stellates are absent; the canal system is eurypylous; the ectosome is not differentiated to form a cortex; the mesoderm is collenchymatous.

Family 3. **STELLETTIDÆ.**—The characteristic flesh spicule is a stellate; other forms may also be present; the canal system is aphodal, but approaches the eurypylous type in the lower forms; the ectosome may, or may not, form a cortex; the mesoderm of the choanosome a sarcenchyme.

Family 4. **GEODINIDÆ.**—The characteristic spicule is the globate; the canal system always aphodal; the cortex always well differentiated; the mesoderm of the choanosome a sarcenchyme.

Sub-order 1.

Family 1. PLAKINIDÆ, Schultze.

Genus 1. *Epallax*, g. n.—Plakinidæ, with large acerate spicules and small quadriradiate spicules.

Epallax callocyathus, sp. n.—Sponge, vasiform, expanding towards the upper margin, which is rounded, and gently undulating, produced into a short, strong slender stalk below, by which it is attached; walls thin; oscules small, opening into the interior of the cup in longitudinal linear series irregularly alternating; pores, in sieves on the outer surface, overlying the incurrent canals, which interdigitate with the excurrent canals, both being wide-branching sinuses produced by a folding of the choanosome. Both surfaces hispid; ectosome thin, collenchymatous; choanosome, a collenchymatous mesoderm; eurypylous flagellated chambers. Spicules—(1) acerate, 3·04 by 0·078 mm.; (2) acerate, 3·93 by

0·039 mm.; (3) calthrops, usually quadriradiate, but frequently tri- and bi-radiate, or sometimes quinqui- and sex-radiate; one ray of a tetrad, 0·0276 by 0·004 mm.; (4) stellates: these differ from the calthrops by possessing more numerous and smaller rays.

Habitat.—Station 192, lat. 5° 49′ 15″ S.; 132° 14′ 15″ E.; 140 fms.

Family 3. **CORTICIDÆ.**

Genus 1. **Thrombus**, g. n.—Corticidæ, containing spined forks like those of *Corticium kittoni*, Carter (*Thrombus kittoni*), see *Ann. Mag. Nat. Hist.*, ser. 4, vol. xiv., p. 24. 1874.

Thrombus challengeri, sp. n.—Mesoderm, a collenchyme which contains numerous oval granular cells, 0·016 to 0·02 mm. in diameter. Spicules like those of *Thrombus kittoni*, but larger; fork, shaft, 0·1 by 0·012 mm.; arms, 0·055 by 0·012 mm.

Habitat.—Station 177; lat. 16° 45′ S.; long. 168° 7′ W.; off Api, New Hebrides, 130 fms.

Sub-order 2.

Family 1. **TETILLIDÆ.**

Genus 1. **Tetilla**, O. Schmidt.—The ectosome never forms a cortex, and is not provided with special spicules; the mesoderm is a collenchyme, and the canal system eurypylous.

Tetilla sandalina, sp. n.—Sponge small; more or less ellipsoidal, or fusiform; a single lateral oscule at one end; ectosome not developed; flagellated chambers large. Spicules—(1) fusiform acerate, 2·326 by 0·0237 mm.; (2) trichite acerates, 0·395 mm. long; immeasurably thin; (3) trifid forks with filiform proximal ends; arms of unequal length; one about 0·197, the other two 0·0513 mm. long; (4) arculi and sigmellæ about 0·025 mm. long; anchors absent.

Habitat.—Azores, lat. 37° 26′ N.; long. 55° 13′ W. 1000 fms.

Tetilla leptoderma, sp. n.—Sponge small; somewhat spherical; a single oscule, lower surface produced into slender rootlets, ectosome thin; flagellated chambers large. Spicules—(1) a fusiform acerate, 4·185 by 0·0474 mm.; (2) trifid forks, filiform at one end, rays of unequal length at the other, 4·03 by 0·0118 mm.;

the longer ray is 0·197, the two shorter, 0·106 mm. long; (3) trichite forks, similar to the preceding, but smaller, and of hair-like fineness; shaft, 1·162 mm. long; (3) somal anchor, a fusiform shaft, with a filiform end, 6·0 by 0·01 mm.; arms, 0·118 by 0·012 mm; (4) radical anchors similar, but with a more massive head, and a distal mucrone; shaft, 6·8 by 0·0276 mm.; arms, 0·154 by 0·0237 mm.; (5) arculi and sigmellæ about 0·0125 to 0·019 mm. long.

Habitat.—Lat. 37° 17′ S.; long. 53° 52′ W. 600 fms.

Tetilla grandis, sp. n.—Sponge large, massive, sub-cylindrical, or sub-ellipsoidal, seated on a massive base of tangled anchoring spicules; oscules numerous, simple; surface hispid; ectosome, a fibro-vesicular collenchyme. Spicules—(1) fusiform acerate, 6·07 by 0·075 mm.; (2) trifid fork; shaft cylindrical; a filiform end; 8·57 by 0·016 mm., to 11·8 by 0·032 mm.; rays, 0·15 by 0·0118 mm.; (3) trichite fork, with one ray longer than the other two; (4) somal anchor, a fusiform shaft with filiform end, 12·14 by 0·02 mm.; rays, 0·16 by 0·012 mm.; spread, 0·16 mm.; (5) radical anchors, similar, but with a thicker head and shorter, stouter rays; shaft, 31·5 by 0·315 mm.; rays, 0·1 by 0·024 mm.; spread, 0·1 mm.; (6) arculi and sigmellæ, 0·0118 mm. long. In small specimens the spicules are smaller; thus, in one 18 by 13 mm. in diameter, the acerate is only 3·5 mm. long, in another, 32 by 26 mm., it is 4·65 mm. long.

Habitat.—Kerguelen and Christmas Island. 10–150 fms.

Tetilla pedifera, sp. n.—Sponge small, somewhat thumb-shaped; surface hispid; oscules numerous, small; ectosome thin, supported by numerous acerates lying parallel to its surface. Spicules—(1) fusiform acerate, 3·2 by 0·03 mm.; (2) forks, a slender shaft, with a filiform end; arms of unequal length, varying from 3 to 1 in number; shaft, 2·38 by 0·012 mm.; arms, long ray, 0·15 mm.; two short rays, 0·06 mm. long; (3) anchors; arms reduced to one, so that the spicule somewhat resembles a shepherd's crook; shaft, 4·46 by 0·0276 mm.; ray. 0·13 mm. long; spread, 0·055 mm.

Habitat.—Lat. 0° 48′ 30″ S.; long. 126° 58′ 30″ E. 825 fms.

Genus 2. **Chrotella**, g. n.—The ectosome is a fibro-vesicular

collenchyme, with acerate spicules strewn through it in various directions, but not at right angles to the surface; the mesoderm is a granular collenchyme; the canal system eurypylous, or aphodal.

Chrotella simplex, sp. n. Sponge somewhat spherical; surface pilose; oscules, one or more, minute. Spicules—(1) fusiform acerate, 3·0 by 0·0237 mm.; (2) trifid fork; shaft, with a filiform end, 3·4 by 0·02 mm.; rays, 0·158 by 0·016 mm.; (3) anchor; shaft, with a filiform end; axial fibre produced distally beyond the origin of the rays; shaft, 5·35 by 0·016 mm.; (4) sigmella and arculus, 0·0118 mm. long.

Habitat.—Lat. 16° 50′ N.; 25° 8′ W. 260 fms.

Chrotella macellata, sp. n.—Sponge spherical, depressed, with a flat base; oscules multiple, each leading into a large cloacal chamber; surface, hispid; flagellated chambers small. Spicules—(1) fusiform acerate, 5·7 by 0·055 mm.; trifid forks, with short prongs, highly porrectate, 0·08 by 0·02 mm.; shaft, fusiform, 7·95 by 0·0276 mm.; (3) trifid fork, with longer rays, less porrectate, 0·23 by 0·02 mm.; shaft, 2·5 by 0·24 mm.; (5) two-pronged (dicellate), and one-pronged (macellate) forks, derived from No. 4 by reduction in the number of the rays; shaft, 3·49 by 0·0316 mm.; prongs of dicellate form, 0·44 by 0·0316 mm.; of macellate, 0·58 by 0·0316 mm.; (6) anchors, shaft, 6·5 by 0·016 mm.; rays, 0·06 by 0·014 mm.; (7) arculi and sigmellæ from 0·012 to 0·016 mm. long; (8) a sigmella with two turns (= a spirula), characterizes the cortex, 0·03 to 0·04 mm. long.

Habitat.—Lat. 11° 37′ N.; long. 123° 31′ E. 18 fms.

Genus 3. **Craniella**, O. Schmidt.—The cortex is differentiated into an inner fibrous, and outer collenchymatous layer; the latter excavated by intercortical cavities; the former traversed at right angles by cortical acerates; the mesoderm of the choanosome is a sarcenchyme; the canal system is aphodal.

Craniella bowerbankii, sp. n.—The spicules include—(1 fusiform acerates of the body, 3·26 by 0·047 mm., and of the cortex 1·4 by 0·04 mm.; (2) forks, with a shaft, 5·12 by 0·024 mm.; rays, 0·12 mm. long.; spread, 0·06 to 0·07 mm.; (3) anchor, 5·8 by about 0·02 mm. The axial fibre of the shaft is continued into the head past the origin of the arms. Arculi and sigmellæ absent.

Habitat.—Port Jackson, var *a.*; Sydney, 35 fms., var. *b.*; Zam boanga, var. *c.*; lat. 10° 30′ S.; long. 142° 18′ E.; 8 fms. This is probably one of the two very different sponges which were named *T. simillima* by Bowerbank.

Craniella pulchra, sp. n.—Spicules—(1) fusiform acerate 4·6 by 0 05 mm. Small acerate of the cortex 1·2 by 0·0395 mm.; (2) trifid fork, shaft 7·1 by 0·0225 mm.; prongs 0.125 mm. long.; (3) anchor, shaft, 8·57 by 0·0165 mm.; rays, 0·0434 by 0·012 mm.; the axial fibre of the shaft extends into the head beyond the origin of the rays.

Habitat.—Lat. 16° 50′ N.; long. 25° 8′ W. 260 fms.

Craniella carteri, sp. n.—Cortex, distinguished by curious cell-aggregates, distributed through its outer collenchymatous layer. These parenchyma-like masses of cells are sharply distinguished from the surrounding tissue, they scarcely stain with reagents, and contain ochreous-coloured spherical granules. Spicules—(1) fusiform acerate, 2·6 by 0·035 mm., and a smaller acerate of the cortex; (2) trifid forks, shaft, 3·5 by 0·014 to 0·016 mm.; rays, 0·0868 by 0·012 mm.; (4) anchors, with rays not quite terminal, the shaft being continued far enough to give a double curvature to the distal margin: shaft, 6·75 by 0·02 mm.; rays, 0·06 mm. long. Arculi and sigmellæ absent.

Habitat.—Bahia.

Craniella schmidtii, sp. n.—Spicules—(1) fusiform acerate, 1·34 to 2·23 by 0·03 mm.; and smaller acerates of the cortex, 0·414 by 0·0276 mm. long; (2) trifid fork, two varieties which pass into each other; one with short, stout, rays, 0·127 by 0·0237 mm.; the other, with longer, slenderer, rays, 0·142 by 0·012; (3) anchors, rays, 0·075 by 0·016 mm.; spread, 0·01 mm.; the axial fibre extends into the head; (4) arculi and sigmellæ, 0·0197 mm. long.

Habitat.—Lat. 38° 30′ N.; long 31° 14′ W.; 1000 fms. This sponge is probably one of those which O. Schmidt has named *Craniella cranium*, which is a purely northern species, and it appears doubtful whether Schmidt had ever seen it.

Genus 4. Cinochyra, g. n.—The ectosome forms a cortex, which consists chiefly of a dense fibrous felt; cortical acerates

traverse it transversely; the innermost layer of the cortex is free from spicules; the cortex is not excavated by intercortical cavities; the oscules and pores are confined to special flasked-shaped recesses; the mouth of each flask is sphinctrate; the walls are perforated by pores which communicate with the incurrent or excurrent canals, as the case may be; the mesoderm of the choanosome is a granular collenchyme; the canal system is eurypylous.

Cinochyra barbata, sp. n.—Sponge sub-spherical or sub-cylindrical, seated on a dense mass of its own anchoring filaments. Oscules and pores as in genus. Spicules—(1) fusiform acerate, 8·03 by 0·71 mm.; and a smaller acerate of the cortex, 0·892 by 0·0355 mm.; (2) forks, a fusiform shaft, 13·21 by 0·0296 mm.; rays, 0·178 mm. long; (3) trichite forks, shaft, 0·13 by 0·004 mm.; rays variable in length, one longer, about 0·03 mm. long; two shorter, about 0·016 mm. long; (4) anchors confined to the lower part of the sponge; shaft from 20·0 to 40·0 by 0·024 to 0·03 mm.; rays, 0·103 by 0·016 mm.; spread 0·118 mm.; (5) arculi and sigmellæ, about 0·0156 mm. long.; (6) globules, 0·0535 mm. in diameter.

Habitat.—Kerguelen, 10 to 150 fms.

Family 2. THENEIDÆ.

Genus 1. **Thenea.**—Sponge of symmetrical form, with specialised poriferous areas. The triana are bifurcated forks, with long secondary rays; and anchors.

Thenea muricata, Bwk.—Occurs in the northern regions of the North Atlantic, not present in the *Challenger* collection.

Thenea schmidtii, sp. n.—Sponge similar to *T. muricata*, Bwk., but distinguished by the large size of its calthrops spicules, and by the comparative thinness of the collenchymatous layer about the canal walls; the rays of the calthrops from 0·175 to 0·205 mm. long.

Habitat.—Station IV., lat. 36° 25′ N.; long. 8° 12′ W.; 600 fms.; station 73, lat. 38° 30′ N.; long. 31° 14′ W.; 1000 fms.; and (O. Schmidt) Florida, 198 fms.

T. grayi, sp. n.—Sponge with a more or less flattened summit and rounded base, which in young forms is hemispherical. Oscule,

large round, laterally placed, poriferous area, also lateral on the opposite side to the oscule: both oscular and poriferous margins fringed with long spicules. Rootlets few and slender. Flagellated chambers, 0·063 mm. in diameter. Spicules—(1) fusiform acerate, 10·07 by 0·026 mm., and 7·8 by 0·08 mm.; (2) porrectate forks, shaft, 5·88 by 0·087 mm.; arms, 0·828 by 0·083 mm.; (3) bifurcated forks, shaft, 5·88 by 0·087 mm.; primary rays, 0·238 by 0·0725 mm.; secondary, 1·193 by 0·06 mm.; (4) somatic anchor, shaft, 1·07 by 0·006 mm.; rays, 0·048 mm. long; spread, 0·09 mm.; (5) radical anchor, 10·33 by 0·0175 mm.; rays, 0·09 to 0·012 mm.; spread, 0·123 mm.; (6) calthrops small, with slender rays, a single ray, 0·143 mm. long; (7) smaller calthrops of usual form; (8) spini-spirulæ, a stout spiral body, 0·0118 mm. long; spines, 0·016 mm. long. Greyish-white.

Habitat.—Station 164 c., lat. 34° 19′ S.; long. 157° 31′ E. 400 fms.

Thenea wyvillii, sp. n.—Sponge, upper surface rounded, cushion-like or flat, with a central, shallow, basin-like depression, in which the excurrent canals open by small, numerous, oscula. Equatorial margin sharp, thin, without a spicular fringe, projecting over the lower surface, which is produced into several strong rootlets, ending below in a tangled spicular base. Poriferous membrane continuous round the equatorial area. Spicules—(1) acerate, 7·85 by 0·07 to 0·084 mm.; (2) porrectate fork, shaft, 6·8 by 0·072 mm.; arms, 0·5 mm. long; (3) bifurcate forks, distinguished by the crooked form of these shafts, which measure 4·28 by 0·0968 mm.; primary arms, 0·178 by 0·08 mm.; secondary, 0·54 by 0·064 mm.; (4) somatic anchors, shaft, 0·876 by 0·008 mm.; rays, 0·95 mm. long; spread 0·1 mm.; (5) radical anchors, 18·2 by 0·011 mm.; rays, 0·1 by 0·014 mm.; (6) calthrops, very regular, triradiate and quadriradiate, as well as other forms; one ray of a quadriradiate measures from 0·08 to 0·09 by 0·0118 mm.; (7) small calthrops; rays, from 4 to 10 in number, about 0·02 mm. long; (8) spini-spirulæ, a slender spiral shaft, and numerous spines, total length, 0·02 to 0·025; length of a single spine, 0·004 mm. Yellowish-white.

Habitat.—Station 209; lat. 10° 14′ N.; long. 123° 54′ W. 95 fms.

T. fenestrata, O. Schmidt.

T. delicata, sp. n.—Sponge, small symmetrical, a conical upper half, sharply defined from a hemispherical lower half; upper surface hirsute; oscule apical; flagellated chambers, 0·087 by 0·067 mm. Spicules—(1) acerate, 6·3 by 0·044 mm.; (2) porrectate forks, shaft, 4·10 by 0·02 mm.; arms, 0·35 mm. long; (3) bifurcate forks, shaft, 4·82 by 0·065 mm.; primary rays, 0·143 by 0·06 mm.; secondary rays, 1·07 by 0·06 mm.; (4) somatic anchors, shaft, 0·954 by 0·008 mm.; rays, 0·075 mm. long; spread, 0·876 mm.; (5) anchoring spicules terminate in rounded club-like heads; shaft, 5·35 by 0·04 mm.; head, 0·0645 mm. wide; (6) calthrops few, small, tending to a spiral form; rays, 0·08 by 0·008 mm.; (7) spini-spirulæ, shaft short and straight, spined at the ends; total length, 0·04 mm. Greyish-white.

Habitat.—Station, 147., lat. 46° 16′ S.; long. 48° 27′ W. 1600 fms.

T. wrightii, sp. n.—Sponge depressed, a flat or obtusely conical upper surface, bearing the oscule; and a flat base; margin more or less lobate; equatorial recess discontinuous; forming a number of circumscribed poriferous areas. Oscular and poral areas not defended by projecting spicules; rootlets absent. The flat cake-like form of the sponge is characteristic.

Habitat.—Station 302, lat. 42° 43′ S.; long. 82° 11′ W. 1450 fms.

Genus 2. **Normania.**—Sponge without specialized porous areas, like those of Thenea; triana; simple forks, without anchors; quadriradiate spicules, as well as calthrops, occur in the choanosome; mesoderm of the choanosome a collenchyme; canal system, eurypylous.

Normania schulzii, sp. n.—A plate-like erect sponge, bearing pores on one surface, and oscules on the other; distinguished from *Normania crassa* by the size of its spicules; the acerates, 3·57 by 0·071 mm.; the forks, shaft, 0·714 by 0·071; arms, 0·357 mm. long.

Habitat.—Station 150; lat. 52° 4′ S.; long. 71° 22′ E. 150 fms.

N. crassiuscula, sp. n.—A plate-like sponge similar in character

of its spicules to *N. schulzii*, but distinguished by the course of the excurrent canals, which run obliquely and longitudinally upwards through the plate to open in patent oscules on one face of the plate.

Habitat.—Porto Praya, St. Jago. 100–128 fms.

N. goliath, sp. n.—Sponge massive, surface raised into sharp undulating ridges, with deep intervening furrows; surface hispid; oscules numerous on the sides and summits of the ridges. Spicules—(1) fusiform acerate, 2·475 by 0·08 mm.; (2) calthrops, each ray 0·684 by 0·05 mm.; (3) acerella, 0·316 by 0·008 mm.; (4) echinella, 0·16 mm. long; (5) globules, 0·16 mm. in diameter.

Habitat.—Station 122; lat. 9° 5′ S.; long. 34° 50′ W. 350 fms.

N. laminaris, sp. n.—Sponge, a thin lamellar expansion 4 to 5 mm. thick; oscules small, dispersed on the inner face. Spicules—(1) a stout fusiform acerate, 3·5 by 0·05 mm.; (2) a slender cylindrical acerate, 5·3 by 0·008 mm.; (3) fork; shaft, 0·678 by 0·06; arms, 0357 by 0·06 mm.; calthrops, acerella, echinella, and spinispirula also present.

Habitat.—Amboyna.

N. tenuilaminaris, sp. n.—This chiefly differs from the preceding species by the greater thinness of the wall, which is from 3 to 3·5 mm. thick. I now only provisionally distinguish it, reserving a final decision to the completed report.

Habitat.—Station 236, lat. 34° 58′ N.; long. 139° 29′ E.; 238–775 fms.

Genus 3. **Vulcanella**, g. n.—Spicules similar to those of Normania; sponge distinguished by the specialisation of the oscula, each the large patent opening of a shallow cloaca, which is lined by a coarsely fenestrate membrane.

Vulcanella cribrifera, sp. n.—Sponge egg-shaped, bearing one or more large oscules on the upper surface; margins of oscules strongly hispid. Spicules—(1) fusiform acerate, 3·04 by 0·067 mm.; (2) slender hispidating acerate, 7·5 by 0·032 mm.; (3) fork, shaft, 1·0 by 0·04 mm.; arms, 0·25 by 0·032 mm.; (4) calthrops

(possibly not proper to the sponge), rays from 0·28 to 0·64 mm. long; (5) acerella, 0·011 mm. long; (6) spini-spirula, 0·016 to 0·02 mm.; (7) cylindrical spicules, with rounded ends (sausage-shaped), 0·357 by 0·028 mm.; these are confined to the cloaca.

Habitat.—St. Jago, Porta Praya.

Genus 4. Characella, g. n.—Similar to Normania, but distinguished by the absence of forks in the choanosome; and by possessing only one form of flesh-spicule, which is an amphiaster form of spini-spirule.

Characella aspera, sp. n.—Sponge irregular in form; growing into irregular ridges, lobes, and folds; oscules numerous; pores generally dispersed or collected within circular depressed areas. Spicules—(1) acerate, 1·476 by 0·073 mm.; (2) forks, shaft from 0·2 to 0·4 by 0·04 to 0·074 mm.; arms, when simple 0·2 to 0·64 mm. long; when bifurcate, primary rays, 0·143; secondary, 0·27 mm. long; (3) acerella, 0·4 by 0·008 mm.; (4) amphiaster, 0·0276 to 0·0434 mm. long; (5) globules 0·05 mm. in diameter.

Habitat.—Station 122; lat. 2° 5′ S.; long. 34° 50′ W. 350 fms.

Family.—STELLETTIDÆ.

The genera of the family Stellettidæ may be arranged in sub-families, as follows:—

A. Stellettidæ with but one form of stellate.

1. Sub-family. HOMASTERINA.

Ectosome not a cortex—**Myriastra**.
Ectosome a cortex.—**Pilochrota**. **Asterella**.

B. Stellettidæ with more than one form of stellate (Heterasterina).

(*a*) Both forms are stellates.

2. Sub-family. STELLETTINA.

Stellates are the only flesh spicules.
Without a cortex—**Anthrastra**.
With a cortex—**Stelletta**.
Trichite sheaves are also present—**Dragmastra**.

(*b*) One form is a stellate, the second a sanidaster.

3. Sub-family. **SANIDASTERINA.**

No other flesh spicules are present—Tribrachium.
Trichite sheaves are present as well—Tethyopsis.

(*c*) One form is a stellate, the second an amphiastrella.

4. Sub-family. **STRYPHNINA.**

A single genus—Stryphnus.

(*d*) One form is a stellate, the other a spined bacillus.

5. Sub-family. **PSAMMASTERINA.**

A single genus—Psammastra.

Although this classification appears to be wholly based on the flesh-spicule, it is not so in fact; but it happens as a remarkable coincidence that differences in the flesh-spicule are as a rule associated with other and profounder differences in the organism: we might easily have brought the latter more prominently forward in this classification, but it would have involved more space than we can here afford.

Genus 1. **Myriaster.**—Sponge small; oscules distinguishable from pores; ectosome thin, mainly collenchymatous, excavated by widely extending sub-dermal cavities, which are never restricted to form chones. Flesh spicules, chiasters only. (The chiaster is a small stellate, with an excessively minute centrum, hair-like rays either abruptly truncated at the ends, or capitate; usually few in number. The typical forms, with few rays and capitate ends, may be fancifully supposed to represent the Greek letter χ, hence the name chiaster). The mesoderm is a sarcenchyme, the flagellated chambers small, usually about 0·02 mm. in diameter; they open by short abiti into the excurrent tubes. Distribution chiefly in Australian seas.

Myriaster subtilis, sp. n.—Sponge small, lobate; a few small oscules. Spicules—(1) acerate, 1·35 to 1·5, by 0·032 mm.; (2) fork; shaft, 1·2 by 0·04 mm.; rays bifurcate; primary rays, 0·042; secondary, 0·16 mm. long; (3) anchor, shaft, 1·16 by 0·012 mm.;

rays, 0·04 mm. long; (4) chiaster; rays capitate, 0·008 to 0·016 mm. in diameter.

Habitat.—Kobei, Japan. 8 to 50 fms.

Myriaster simplicifurca, sp. n.—Sponge small; a single oscule on upper surface. Spicules—(1) acerate, 2·0 by 0·0316 mm.; (2) fork, shaft, 2·325 by 0·055 mm.; arms, simple, 0·37 by 0·054 mm.; (3) anchor, shaft, 1·86 by 0·03 mm.; rays, 0·12 mm. long; (4) chiaster, 0·012 mm. in diameter.

Habitat.—Station 186, lat. 10° 30′ S.; long. 142° 18′ E. 8 fms.

Myriaster toxodonta, sp. n.—Sponge small; a few small oscules. Spicules—(1) acerate, 3·42 by 0·032 mm.; (2) fork, shaft, 3·5 by 0·05 mm; arms, bifurcate; primary rays, 0·095 to 0·127 mm. long; secondary, 0·29 to 0·32 mm. long; (3) anchor, shaft, 3·6 by 0·024 mm.; rays, 0·1114 mm. long; (4) chiaster, 0·01 to 0·016 mm. in diameter.

Habitat.—Station 203, lat. 11° 6′ N.; long. 123° 9′ E. 20 fms.

Myriaster clavosa, Ridley.

Habitat.—Stations 186 and 208.

Myriaster quadrata, sp. n.—Sponge small, a single small oscule. Spicules—(1) acerate, 2·56 by 0·016 mm.; (2) fork, shaft, 3·2 by 0·028 mm.; arms, bifurcate; primary rays, 0·11 mm., secondary rays, 0·27 mm. long; (3) anchor, shaft, 3·14 by 0·02 mm.; rays, 0·1 mm. long; (4) chiaster, 0·008 mm. in diameter.

Habitat.—Station 212, lat. 6° 54′ N.; long. 122° 18′ E. 10 fms.

Genus 2. **Pilochrota**, g. n.—Oscules distinct, pores in sieves overlying incurrent chones; ectosome, thick fibrous cortex; flesh spicules, chiasters; choanosome, as in Myriaster. Distribution: Australian seas, Tahiti, West Indies, S. Atlantic.

Pilochrota haeckeli, sp. n.—Sponge sub-globular; oscule single. Spicules—(1) acerate, 2·07 by 0·046 mm.; (2) fork, shaft, 2·18 by 0·055 mm.; arms, simple, 0·24 to 0·32 mm.; (3) anchor, shaft, 3·03 by 0·035 mm.; rays, 0·16 mm. long; (4) small acerate of the cloaca; (5) chiaster, 0·016 mm. in diameter.

Habitat.—Zamboanga. 10 fms.

P. anancora, sp. n.—Sponge small, spherical, depressed, oscule single. Spicules—(1) acerate, 1·68 by 0·023 mm., to 3·18 by 0·023 mm.; (2) fork, shaft, 1·63 by 0·0276 mm.; arms, simple, 0·127 mm. long; (3) chiaster as usual.

Habitat.—Bahia. 7–20 fms.

P. gigas, sp. n.—Sponge massive; several large oscules on the upper surface. Spicules—(1) and (2), 3·18 by 0·024 mm.; acerate, 1·7 by 0·039 mm.; (3) fork, shaft, 1·96 by 0·039 mm.; arms, 0·223 mm. long; (4) chiaster, capitate rays, 0·013 mm. in diameter.

Habitat.—St. Paul's Rocks.

P. tenuispicula.—Sponge small, oscule single. Spicules—(1) acerate, 1·35 to 2·3, by 0·016 mm.; (2) fork, shaft, 1·6 by 0·016 mm.; arms, 0·12 mm. long; (3) chiaster; rays not capitate, 0·012 mm. in diameter.

Habitat.—Bermuda, W. Indies.

P. pachyderma, sp. n.—Sponge massive, lobate, free, two or more oscules on the upper surface; cortex very thick. Spicules—(1) acerate, 1·193 by 0·0178 mm.; (2) fork, shaft, 1·114 by 0·022 mm.; arms, simple, 0·12 mm. long; (3) anchor, shaft, 1·35 by 0·0158 mm.; rays, 0·067 mm. long; (4) chiaster, rays abruptly truncate, but not capiate, 0·006 to 0·011 mm. in diameter; colour, purplish.

Habitat.—Tahiti. 30–70 fms.

P. crassispicula, sp. n.—Sponge irregularly spherical; free; oscule single. Spicules—(1) acerate, 3·5 by 0·024 mm., and 2·3 by 0·052 mm.; (2) fork, shaft, 2·36 by 0·08 mm.; arms, 0·254 mm. long; (3) chiaster, rays capitate; from 0·012 to 0·02 mm. in diameter.

Habitat.—Bahia. 7 to 20 fms.

P. purpurea, Ridley.

P. longancora, sp. n.—Sponge small; a single circular oscule, having the margin fringed by minute acerates projecting radiately in the plane of the apertures. Spicules—(1) acerate, 1·63 by

0·035 mm.; (2) fork, shaft, 2·1 by 0·047 mm.; arms, simple, 0·35 mm. long; (3) anchor, shaft, 3·5 by 0·024 mm.; rays, 0·075 mm. long; (4) minute acerate of oscular margin; (5) chiaster, 0·009 mm. in diameter in the ectosome, 0·012 mm. in choanosome.

Habitat.—Torres Straits. 3–11 fms.

Genus 3. Anthastra, g. n.—Sponge usually more or less spherical; oscules distinguishable from the pores or not; ectosome thin, chiefly collenchymatous, excavated by extensive sub-dermal cavities which never form chones; choanosome as in Myriaster. Flesh spicules an anthaster and usually a chiaster. (The anthaster is a stellate with conical or bacillar microspined rays, which may be numerous but are usually few in number, and may be reduced to two, when a spined bacillus is the result.) Distribution: Australian seas, and Japan.

Anthastra communis, sp. n.—Sponge more or less spherical, free or attached; oscules not distinguishable from the pores. Spicules —(1) acerates 4·2 to 5·6 by 0·06 to 0·09 mm. (2) fork with bifurcated arms, primary rays projecting forwards and outwards, sometimes more outwards than forwards, sometimes the reverse, then giving the head a cyathi-form appearance, secondary rays horizontal, shaft, 4·4 to 5·7 by 0·09 to 0·11 mm.; primary rays, 0·14 to 0·16; secondary, from 0·52 to 1·114 mm. long; (3) anchor, shaft, 3·0 to 4·3 by 0·32 to 0·39 mm.; rays, 0·127 to 0·16 mm. long.; (4) anthaster, rays few, 0·02 to 0·03 mm. long; (5) chiaster, spines numerous, 0·006 to 0·008 mm. long; colour, greyish-white, sometimes russet-red (owing to presence of algal cells?).

Habitat.—Station 162, lat. 39° 10′ 30″ S.; long. 146° 37′ E.; 38 fms. Station 162a; lat. 36° 59′ S.; long. 150° 20′ E.; 150 fms. Port Jackson, 6 to 15 fms.

Anthastra pulchra, sp. n.—Sponge small, globular, free, a single oscule. Spicules—(1) acerate, 2·4 to 3·1 by 0·0315 mm.; (2) fork with simple arms, shaft, 2·6 to 2·9 by 0·0474 mm.; arms, 0·26 mm. long; (3) anchor, shaft, 2·6 to 2·9 by 0·0315 mm.; rays, 0·125 mm. long; (4) anthaster, rays few, 0·016 mm. long; (5) chiaster, variable in character, rays seldom capitate.

Habitat.—Station 163 a.; lat. 36° 59′ S.; long. 150° 20′ E. 150 fms.

Anthastra parvispicula, sp. n.—Sponge small, spherical, free, a single small oscule. Spicules—(1) acerate 1·3 by 0·02 mm.; (2) fork with simple arms, shaft, 1·75 by 0·02 mm.; arms, 0·21 mm. long; (3) anchor, shaft, 1·3 by 0·016 mm.; rays, 0·045 mm. long; (4) anthaster as in *A. pulchra;* (5) chiaster, rays not capitate, 0·0118 mm. long.

Habitat.—Station 161; lat 38° 21′ 30″ S.; long. 144° 36′ 30″ E. 33 fms.

Genus 4. **Ecionema**, Bwk.—Similar to Anthastra, but with the oscules confined to the summit, the excurrent tubes running longitudinally and vertically through the sponge.

Ecionema ridleyi, sp. n.—Sponge ovate, several small oscules on the summit. Spicules—(1) acerate, 4·07 by 0·118 mm.; (2) fork, with simple arms, 4·3 by 0·118 mm.; arms, 0·27 to 0·32 mm. long; (3) anchor, shaft, 3·6 by 0·03 mm.; rays, 0·103 mm. long; (4) anthaster, small; rays few or numerous; a single ray of a tetrad form, 0·01 by 0·004 mm.; (5) chiaster, rays slender, hair-like, capitate, 0·016 mm. in diameter.

Habitat.—Port Jackson. 30–35 fms.

Ecionema pyriformis, sp. n.—Sponge obconic, attached by flat base, summit bearing numerous small oscules; pores in sieves, generally distributed over the sides; chief excurrent canals vertical. Spicules—(1) acerate, 3·14 by 0·095, to 4 by 0·104 mm.; (2) fork, shaft, 3·02 by 0·095, to 3·72 by 0·163; arms bifurcate; primary rays, 0·1114, secondary rays, 0·1114 to 0·175 mm. in length; (3) anchor, shaft, 2·1 by 0·023 mm.; rays, 0·016 mm. long; (4) anthaster, bacillary rays with rounded ends, microspined, usually 4 to 7 in number; a single ray of a tetrad form, 0·013 by 0·004 mm.; (5) chiaster rays capitate, 0·008 mm. long.

Habitat.—Port Jackson. 30 to 35 fms.

Genus 4. **Stelletta**, Schmidt.—Ectosome a thick cortex, traversed by chones. Spicules, two kinds of stellates, one with conical pointed rays.

Stelletta phrissens, sp. n.—Sponge, globular or cylindrical, attached; surface hispid, with spicules which project 6 to 7 mm. beyond it; oscules small, congregated; pores in sieves; cortex thick,

the outer collenchymatous layer without spicules. Spicules—(1) acerate, 4·75 by 0·07 mm.; (2) fork, shaft, 3·5 to 4·2, by 0·12 mm.; rays bifurcate; primary rays about half the length of secondary, which are 0·3 mm. long; (3) anchor, shaft, 8·72 by 0·06 mm.; (4) stellate sharp conical rays, small centrum; rays from 0·02 to 0·027 mm.; (5) pycnaster, a comparatively large centrum, provided with numerous short spines, with truncated ends, 0·01 mm. in diameter.

Habitat.—Station 308, lat. 50° 8′ 30″ S.; long. 74° 41′ W. 175 fms.

Genus 5. **Astrella**, g. n.—Like Stelletta, but with only one form of stellate, a pycnaster, i. e. with a small centrum, and short blunt, numerous, rays.

Astrella vosmaeri, sp. n.—Sponge, beehive-shaped, oscules not distinguishable from the pores. Spicules—(1) acerate, 3·14 by 0·06 mm.; (2) fork, shaft, 3·02 by 0·08 mm.; arms bifurcate; primary rays, 0·088, secondary, 0·24 mm. long; (3) anchor, shaft, 3·61 by 0·028 mm; arms, 0·04 mm. long; (4) pycnaster, a comparatively large centrum and short, thick, truncated rays, 0·012 to 0·016 mm. in diameter.

Genus 6. **Dragmastra**.—Like Stelletta, but with a layer of trichite sheaves in the cortex. Type, *Dragmaster* (Stelletta) *normani* (Sollas), Norway.

Genus 7. **Stryphnus**, g. n.—Stellettidæ distinguished by the absence of a radiate arrangement of the spicules of the choanosome, only those which immediately approach the surface of the sponge being arranged at right angles to it; by the comparatively small size and rarity of the fork spicules as compared with the acerates, and chiefly by the presence of a curious irregular flesh-spicule—the amphiastrella. The cortex is a vesicular collenchyme containing pigment cells.

Stryphnus niger, sp. n.—Sponge, compound, massive, oscules large, collected in groups. Spicules—(1) acerate, 2·4 by 0·61mm.; (2) fork, shaft, 0·446 by 0·0356 mm.; arms bifurcate; primary rays, 0·055, secondary, 0·079 mm. long; (3) anchors; (4) stellate, a small centrum and numerous slender conical-shaped pointed rays, 0·014 mm. long; amphiastrella, various, typically a short cylin-

drical shaft with a whirl of spines at each end; the spines may be sharp, but are more usually stunted and rounded off, or the spines may be given off quite irregularly from all parts of the shaft; 0·016 by 0·012. Colour, deep puce black.

Habitat.—Port Jackson. 30–35 fms.

Stryhnus unguicula, sp. n.—Sponge similar to *S. niger*. Distinguished by the forks, the arms of which are bifurcate, with the primary rays extending only slightly forward, and the secondary rays diverted backward; each pair of the latter, also, after diverging from each other in the usual way, are approximated so as to run parallel to each other for the last half of their course; shaft, 0·508 by 0·032 mm.; primary rays, 0·0276, secondary rays, 0·04 mm. long.

Habitat.—Port Elizabeth, S. Africa (not in *Challenger* Collection).

Genus 8. **Tribrachium**, Weltner.—Sponge, a spherical body, produced into an excurrent tube, but not into a special incurrent tube. Spicules—forks, with only two arms in the excurrent tube, with three arms in the cortex of the body; acerates, anchors, rarely stellates, and numerous sanidastra.

Genus 9. **Tethyopsis**, Stewart.—Sponge, a special poral tube at one pole of the spherical body and a special oscular tube at the other; canal system arranged on a radiate plan, primitively four excurrent canals, alternating with four incurrent canals. Spicules—reduced forks in the excurrent tube; forks with three arms, or only two or one in the cortex of the body, acerates, but no anchors; in the poral tube acerates, no forks or anchors; flesh-spicules are stellates, sanidastra, and trichite sheaves.

Genus 10. **Psammastra**, g. n.—Sponge, with a thick fibrous cortex incorporating grains of sand; oscules, two or more; surface raised into conuli; spicules—a stellate with short rays and large centrum, and another form with smaller centrum and larger rays, also, and most numerous spined bacilli; forks of very peculiar character, rays very short, appearing merely as spines of an acerate spicule with a rounded distal end.

Psammastra murrayi, sp. n.—Sponge spherical, with two or three oscules; surface raised generally into conuli, and produced here and there into strong fibrous bands for attachment; cortex thick, containing imbedded grains of sand. Spicules—(1) acerate, 4·65, and over, by 0·065 mm.; (2) fork, 3·9 by 0·071 mm.; arms simple, regularly curved outward and forward, 0·097 to 0·116 mm. long; spread, 0·161 to 0·175 mm.; (3) modified fork; a conical spicule, with rounded distal base, and three short spines given off near the distal end; the axial ray of the spines descends outwards and downwards through the spicular shaft, but bends into horizontal position as it enters the rays or spines, which may be simple or bifurcate, the bifurcation taking place in a horizontal or vertical plane; (4) stellates, a variety with large centrum and short rays, 0·012 to 0.016 mm. in diameter, passing into a second variety with small centrum and longer rays, 0·016 to 0·024 mm. in diameter; (5) bacillus, a cylindrical rod with rounded ends, microspined irregularly over the whole surface; sometimes constricted in the middle, 0·018 to 0·016 by 0·004 mm. Colour, russet brown on upper surface where exposed to the light; pale grey below.

Habitat.—Station 162, lat. 39° 10′ 30″ S.; long. 146° 37′ E. 38 fms.

Family. **GEODINIDÆ.**

Genus	1.	**Erylus, Gray.**	Genus	4.	**Synops, Vosmaer.**
,,	2.	**Caminus, Schmidt.**	,,	5.	**Isops, Sollas.**
,,	3.	**Cydonium, Müller.**	,,	6.	**Geodia, Lamk.**

Of the genus Geodia no examples occur in the *Challenger* Collection.

Synops is an exceedingly natural genus, characterized, not only by the restriction of the oscules to one surface, but also by the general characters of its spicules; anchors rarely occur, and the arms of the forks are usually simple.

Description of Species.

Erylus formosus, sp. n.—Sponge massive, growing into ridges and lobes, attached; oscules round, few; pores large, each the simple opening of an incurrent chone. Spicules—(1) acerate, 0·9 by 0·024 mm.; (2) fork, shaft, 0·4 by 0·024 mm.; arms simple;

(3) globate, shaped like a finger biscuit, or shuttle-shaped, or lozenge-like, surface granulated, 0·14 by 0·032, to 0·175 by 0·026 mm., or narrower and longer, 0·2 by 0·024, or shorter and wider, 0·122 by 0·048 mm.; thickness, from 0·008 to 0·01 mm.; (4) fusite, 0·07 by 0·006 mm.; (5) large stellate, with few rays, 0·063 mm. in diameter, a single ray, 0·032 mm. long; (6) small stellate, a small centrum, and numerous short rays, truncated, or capitate at the ends, 0·016 mm. in diameter.

Habitat.—Bahia. 7–20 fms.

Caminus sphæroconia, sp. n.—Sponge massive, with massive vertical lobes, attached; oscules on summits of lobes, large, leading into large cloacas; pores in sieves, roofing incurrent chones. Spicules—(1) acerate, 0·5 by 0·016 mm.; (2) fork, shaft, 0·32 by 0·016 mm.; arms simple, 0·2 mm. long; (3) globate, 0·0553 mm. in diameter; (4) globule, a minute, smooth sphere, 0·004 mm. in diameter; this serves both as ectaster and endaster; colour, purplish when exposed to the light; yellowish below.

Habitat.—Bahia, shallow water.

This sponge is very similar to *Caminus vulcani*, O. S., which also contains true forks and globules; it differs by the absence of stellates, which are present in *C. vulcani*, and by the less length of its acerate spicules (0·08 by 0·016 mm. in *C. vulcani*), and by the smaller size of the globule (0.1 mm. in diameter in *C. vulcani*). The cortex is about 0·8 mm. thick, and consists of an ecto-cortex formed of vesicular tissue, 0·05 to 0·24 mm. thick, of a globate layer, 0·65 mm. thick, and an inner fibrous layer, 0·05 to 0·08 mm. thick.

Cydonium glariosus, sp. n.—Sponge, more or less spherical, attached; the collenchymatous ecto-cortex is crowded with coarse grains of sand, and traversed by pencils of short acerates, which are entirely confined to it. Spicules—(1) acerate, 1·86 by 0·026 mm.; (2) small acerates of the cortex, 0·35 to 0·4, by 0·016 mm.; (3) fork, shaft, 2·86 by 0·052 mm.; arms simple; (4) second form of fork, shaft, 5·36 by 0·03 mm.; arms simple, 0·08 to 0·11 mm. long; (5) anchor, shaft, 4·65 by 0·012 mm.; rays, 0·08 mm. long; (6) globate, spherical, 0·05 to 0·058 mm. in diameter; (7) ectaster, small centrum, short rod-like rays, 0·01 mm. diameter; (8) en-

daster, centrum small, rays conical pointed, or rod-like truncated, 0·016 to 0·0193 mm. in diameter. Colour, purplish white.

Habitat.—Bahia. 7 to 20 fms.

Cydonium magellani, sp. n.—Sponge large, attached; surface hispid. Spicules—(1) acerate, 3·93 by 0·052 mm., to 2·71 by 0·058 mm.; (2) fork, shaft, 3·93 by 0·064, to 4·82 by 0·09 mm.; arms bifurcate; primary rays, 0·13, secondary, 0·275 mm. long; (3) anchor, shaft, 7·4 by 0·02 mm.; rays, 0·15 mm. long; (4) globate, spherical, depressed, 0·123 by 0·103 mm.; (5) ectaster; a fairly large centrum, numerous rod-like rays, 0·0118 mm. in diameter; (6) endaster, a globo-stellate, 0·217 mm. in diameter.

Habitat.—Stations 308 and 311. 175 and 245 fms.

Cydonium hirsutus, sp. n.—Sponge irregular lobate; surface hispid, spicules projecting 8 or 9 mm. beyond it, cortex thick. Spicules—(1) acerate, 4·5 by 0·06 mm. to over 9·0 by 0·032 mm.; (2) fork, shaft over 4·46 mm. long by 0·084 to 0·05 wide; arms bifurcate, primary arms, 0·13; secondary, 0·35 mm. long; (3) second form of fork, shaft long, diameter, 0·2 mm., arms simple 0·13 mm. long; (4) anchor, shaft, long, 0·018 mm. in diameter; rays, 0·036 mm. long; (5) globate, a flattened prolate ellipsoid: 0·306 by 0·245 by 0·161 mm.; (6) ectaster, a small centrum, and blunt conical rays, 0·012 mm. in diameter; (7) endaster, a small centrum, and a few slender conical rays, 0·02 mm. in diameter: a small globo-stellate is present, but does not belong to the sponge.

Habitat.—Station 192; lat. 5° 49′ 15″ S.; long. 132° 14′ 15″ W.; 140 fms.

Synops vosmaeri, sp. n.—Sponge cylindrical, a cup-shaped depression at the summit, erect, attached, oscules confined to the summit; pores in sieves on the sides, roofing incurrent chones. The ecto-cortex contains ectasters scattered throughout it; the globate layer is thin, and the fibrous layer remarkably thick. Spicules—(1) acerate, from 1·3 by 0·016 to 1·7 by 0·008 mm.; (2) acerate of the cortex, 0·3 by 0·004 mm.; (3) fork, shaft, 1·1 by 0·039 mm.; arms, simple, 0·29 mm. long; (4) globate, small, spherical, 0·04 mm. in diameter; (5) ectaster, a small centrum, short spines, with rounded ends, 0·004 mm. in diameter; (6) en-

daster, long hair-like rays, not numerous, 0·026 mm. in diameter.

Habitat.—Station 122; off Barre Grande. 350 fms.

Synops nitidus, sp. n.—Sponge plate-like, horizontal, oscules numerous, small, restricted to the upper surface over which they are dispersed; pores in sieves on the opposite surface; cortex—beneath the epithelium is a layer of small globo-stellates, this is succeeeded immediately by the globate layer, which constitutes almost the whole of the cortex. Spicules—(1) acerate 1·25 by 0·026 mm.; (2) fork, shaft, 1·07 by 0·039 mm., arms simple, 0·183 mm. long; (3) ectaster, a globo-stellate, 0·0135 mm. in diameter; (4) endaster, a small centrum, and long conical microspined rays, usually few in number, 0·044 in diameter.

Habitat.—Port Jackson, Sydney. The smooth, shining, upper surface is very characteristic, and no other species of Synops presents the same horizontally spreading form.

Synops neptuni, sp. n.—This is the largest tetractinellid sponge known. It has the form of a somewhat conical cup with a large central cavity, rising from a base of 12 cm. diameter to a height of 40 cm.; where broadest its diameters are 22 cm. and 31 cm. Its wall is intricately folded. The oscules are confined to the inner surface of this cup.

Habitat.—Station 122; off Brazil. 32 fms.

Isops pachydermata, sp. n.—Sponge, irregular, massive; surface smooth; oscules and pores singly perforating small rounded bosses; cortex thick, constituted almost entirely of the globate layer; beneath the epithelium a layer of globo-stellates. Spicules—(1) acerate, 1·96 by 0·052 mm.; (2) fork, shaft, 1·07 by 0·039 mm.; arms simple, 0·27 mm. long; (3) globate, a compressed ellipsoid, 0·24 by 0·19 mm. in diameter; (4) ectaster, a globo-stellate, 0·016 in diameter; (5) endaster, centrum small, spines conical, sharply-pointed, few; single ray of a triad form, 0·064 mm. long; (6) a stellate intermediate between (4) and (5).

Habitat.—Station 56; lat. 32° 8′ 45″ N.; long. 64° 59′ 35″ W. 1075 fms

Definition of Terms.

Ectosome.—The outer layer of the sponge, not containing flagellated chambers.

Choanosome.—The "mark" or "parenchyma," distinguished by the presence of flagellated chambers.

Eurypylous.—When the flagellated chambers communicate by wide mouths directly with the excurrent canals.

Aphodal.—When they do so by narrow canaliculi.

Collenchyme.—Gelatinous connective tissue.

Sarcenchyme.—A collenchyme in which the *collenchytes* or branching stellate cells are replaced by granular polygonal contiguous cells.

Triana.—Tetrad spicules with a differentiated shaft—forks, and anchors.

XXV.—IRISH METAL MINING. By G. H. KINAHAN, M. R. I. A., Etc.

[Read, March 24, 1886.]

The lists of mines published by Griffith in the *Dublin Quarterly Journal of Science* (1861) were corrected and revised in chap. xxi. section v. pp. 361, &c., of the *Geology of Ireland* (1878); but these now require revision. It is therefore proposed to again revise and, at the same time, to re-arrange them, first giving separate lists for each mineral arranged in counties, or in "fields" where the ores are bedded, with, subsequently, short County Histories of the mines, thus dividing the subject into two parts.

In both parts the Counties, as far as possible, will be arranged alphabetically. In Part I. the lists include all the places where the different minerals are recorded as found in appreciable quantities; and in Part II., when possible, the present state of the lodes will be stated; but in both Parts, in the majority of cases, the information given as to the work done, on account of the unsatisfactory way in which the old mining records and statistics were kept, will be on hearsay evidence. The statements, therefore, cannot be taken as perfectly satisfactory, as a large portion may require to be substantiated.

The history of the early Irish mining adventures is very scant, the records being vague. The ancient mines are referred to by Griffith, Kane, and other modern explorers; but necessarily the remarks had to be more or less vague, and do not give much information. Griffith, however, states:—"Many of our mining excavations exhibit appearances similar to the surface workings of the most ancient mines in Cornwall, which are generally attributed to the Phœnicians."

The late R. Rolt Brash published an interesting Paper on "The Precious Metals and Ancient Mining in Ireland" (*Journal Roy. His. Arch. Ass. Ireland*, vol. i., fourth series, p. 509); but it more particularly refers to the "finds" of gold and silver articles; these metals having been worked and mined at an early date. Bronze implements are also very ancient, and possibly iron; but the latter metal corrodes away so fast that all ancient implements must have disappeared long since; though traces of them may sometimes be found. It may be mentioned that deep down among the records of the earliest inhabitants of the large crannog in Lough Rea, Co. Galway, I found a rod of rust that evidently was the remains of an iron implement; it must have been 2000, or 3000, or more, years old.

Of Ancient Metal Mining, or its Adjuncts.—A very early record occurs in the *Annals of the Four Masters*, A. M., 3656, where gold is mentioned as procured in *Foithue Airthir Liffe*, or in the mountains of Dublin and Wicklow; while at *Lyra*, *Knockmiller*, about two miles southward of Woodenbridge, Co. Wicklow, the ancient timberings in a placer mine were found. We also learn from the Annals that in A.M. 3817 silver shields were made at *Argetros* (Silverwood) on the Nore, Co. Kilkenny. In this neighbourhood are the remains of ancient mines at Ballygallion and Knockadrina—places at which in recent years native silver has been found. It appears probable that, in those early times, some at least of the silver was procured at those mines; there are, however, other prehistoric mines that probably were also sources from which silver was procured. There is also mentioned in the Annals; silver, got at *Rosargid* (which also means Silverwood), near Toomavara, Co. Tipperary. That name has not descended to us; but at Garrane, adjoining *Kilnafinch*, a little southward of Toomavara, is the *debris* of an ancient mine, locally called the "Silver Mine." Further westward, south of Nenagh, are the village and mines of Silvermines. Some of the mines at this village were worked so long ago, that when opened, about the year 1860, the attals (*pyrite* and *sphalerite*) in the stulls and old levels were found to have undergone a complete chemical change—into peroxide of iron, with carbonate and silicates of zinc. In recent years some of the lead from this locality has given as much as eighty ounces of silver to the ton, in addition to some native silver. Still, further west-

ward, at *Garrykennedy*, on Lough Derg, "old men's workings" were broken into about the year 1855, and in them were found a man's skeleton and the remains of wooden and stone tools. To the westward of the Shannon, at *Milltown*, near Tulla, Co. Clare, a mine was worked in ancient times. Here there is native silver; the oaken shovels and large iron picks found suggesting that the workings were not as old as some of the others. At *Carhoon*, near Tynagh, Co. Galway, there are the relics of an ancient mine of which the traditions are extinct. In south-east Ireland, at the *Magpie* or *East Cronebane* (Ovoca), Co. Wicklow, there are "old men's workings," on the "gossan lode," and in them were found stone and wooden implements. Here native silver was also found.

From so many of these ancient mines being on silver-lead lodes, it may be suggested that the "old men" understood a process for separating the silver from the lead.

Nennius, who wrote in the ninth century, mentions the mines of Lough Leane, Killarney; while about the year 1804, when Col. Hall was working the lead mine at Ross Island, he found primitive levels, stone implements, and other records of ancient work.

At Derrycarhoon, near Ballydehob, Co. Cork, in an old working, there were wooden and stone implements, a curved tube of oak, and a primitive ladder—the latter being an oak pole, with rude steps cut in its sides. This working must have been very ancient, as when found all traces of the surface entrance were smothered up by a growth of peat, over fourteen feet deep; this ought to represent a period of, at the least, 3000 years or more.

About the year 1850 wooden tools, shod with iron, were found in ancient galleries, in connexion with the coal seam of the Ballycastle coal-field, Co. Antrim; while wooden scoops were found in an old working for bog-iron in the Queen's County, some of them being now in the Royal Irish Academy Museum.

During the rush after Irish mines, about twenty-five or thirty years ago, their characters were considerably prejudiced, and the working of them retarded, by a class of "Promoters," who misrepresented them; also by incautious Analysts, who represented the ores more favourably than they were entitled to. Such proceedings are most damaging to a mine; for although it may be good of its kind, and be capable of paying well, if judiciously worked, when it cannot give the "riches" promised, it gets into disrepute;

or, if it is injudiciously over-worked, to try and keep up its fictitious character, it will be robbed and its future prospects ruined.

In the history of the mining during those years, it is now well known, that more than one Promoter exhibited specimens as representing the ordinary minerals of a lode, while in reality his sample exhausted all the mineral of that class to be found in the veins. Also, some Analysts, after examining a specimen, allowed their analyses to be published as if they were the representative analyses, although they were ignorant whether the portion submitted to them was a true specimen, representing the average ore of the lode, or a picked one that only represented its riches. An honest, true representation of the value of the minerals of a lode is most important, and the neglect of such, or the intentional misrepresentation of the value of the lode, has led to most disastrous results, not only in Ireland, but all over the world. Careless analysts and intentional misrepresentations cannot, therefore, be too highly censured.

In drawing out the lists of Irish mines and minerals the products have been arranged in the following order:—Gold, tin, native silver, lead and zinc, copper, sulphur ores and gossen, barytes, iron, manganese, antimony, arsenic, cobalt, graphite, nickel, titanium, molybdenite, alum and copperas, apatite, salt and gypsum, steatite and pyrophyllite: the products being arranged as much as possible in regard to the natural grouping of the ores in the veins.

Some of the minerals in the above list have been very sparingly looked after, and their occurrence may be much more frequent than is hereafter mentioned, as the lists are compiled from the localities observed and recorded by the different explorers. This may be specially the case in reference to some minerals that, although observed, have not been recorded. Boate, in his notice of the silver mines, Co. Tipperary, records quicksilver as found prior to 1640. In modern times no trace of this ore is recorded.

Some of the Irish rocks are said to be Pre-Cambrian, but the only pretension for classing them as Laurentians is *their lithological characters.* Some of these so-called Pre-Cambrian, both Petrologically and Palæontologically, are evidently, in one case Ordovician and in another Cambrian; while elsewhere they apparently belong to one or other of these periods.

In the Lists the Names used for the Geological Groups are those given in the following Table:—

TABLE OF GEOLOGICAL STRATA.

Names.			Remarks.
Tertiary or Cainozoic.		Pliocene.	
		Miocene.	
		Eocene.	
Secondary or Mesozoic.		Cretaceous.	
		Jurassic.	
		Triassic.	
Primary or Palæozoic.	Upper Series.	Permian.	**Passage beds.**
		Carboniferous.	Coal Measures and Limestones, &c.
	Second Series.	Devonian.	**Passage beds** (Yellow and Old Red Sandstone).
		Silurian.	Upper Silurian.
	Third Series.	Mayhill Sandstone or Llandovery.	**Passage beds.**
		Ordovician.	Cambro- or Lower Silurian.
	Lower Series.	Arenig beds.	**Passage beds.**
		Cambrian, or Primordial.	Primordial appears to be preferred on the Continent and in America.

The *Passage beds*, Arenig and Devonian, are complete in the Irish strata; the others, Mayhill Sandstone and Permian, are only in part represented. (See "Irish Lower Palæozoic Rocks," *Scien. Proc. R. D. S.*, vol. III., p. 34, May, 1885.)

Part I.—LIST OF THE IRISH MINES AND MINERALS.

[The localities where there were mines or trials are printed in italics. The nearest town and the names of the Rock-formation are given in the column of Remarks.]

GOLD.

Counties.	No. of Ordnan'e Sheet.	Localities.	Remarks.
Antrim.		Slieve-an-Orra.	Glendun—*Diluvium.*—Said to have been found about thirty years ago in Glendun burn.
Carlow.		*St. Mullin's.*	St. Mullin's—*Diluvium.*—The exact place where the gold was found is unknown, but it is supposed to have been in the streams of Slievebaun (White Mountains).
Cork.	147	*Carrigacat* or *Dhurode.*	Crookhaven—*Yellow Sandstone,* or *Devonian.*—In the gossan of the copper loads. Near Ballydehob, in this promontory, is the copper mine of Skeaghanore (*whitethorn bush of the gold*). No gold, however, has been recorded from this mine.
,,	146	*Kilcrohane* (Sheep Head).	
Donegal.	107	Knaderlough.	Ballyshannon—*Cambrian* (?).—See County Histories.
Dublin.		Ballinascorney and Rathfarnham.	Dublin—*Diluvium.*—In the gravel of the River Dodder.
Londonderry.		Moyola River.	Draperstown—*Diluvium.*—This is a locality mentioned by Gerrard Boate, A.D. 1652; but no gold has been found in recent years. The nature of the rocks and minerals in the county where this river rises would suggest the possibility of there being stream-gold in the valley.
Wicklow.	40	*Darragh-water* or *Aughrim River.*	Woodenbridge—*Diluvium.*—In the gravel of this valley and the tributary valleys; namely, Goldmine valley and its tributaries, Kilacloran stream, Coolballintaggart stream, valley of the Ow and its tributaries, and the Kilmacreddan burn.
,,	34	Ballymanus.	Aughrim—*Metamorphic Ordovician.*—Particles of gold in a quartz vein, discovered by *Gerrard A. Kinahan.*

Counties.	No. of Ordnance Sheet.	Localities.	Remarks.
Wicklow.	35	Castlemacadam.	Ovoca—*Diluvium.*—In the gravel of the Ovoca river; south of the Railway Station.
,,	35	*Ballymurtagh.*	Ovoca—*Ordovician.*—In the gossan and gossan lodes of the mines on the *Ovoca mineral channel* gold has been detected; also in places in the regular ores of the lodes. The gossan lode of East Cronebane (*Magpie Mine*) seems to have been richest. In places, the Kilmacooite, or "Blue-stone," of the Magpie and Kilmacoo are also auriferous.
,,	35	*Tigroney.*	
,,	35	*Cronebane.*	
,,	35	*Connary.*	
,,	35	*Kilmacoo.*	
,,	40	*Ballycoog.*	
,,	40	*Ballinasilloge.*	
,,	39	*Moneytiegne.*	
,,	8	Greystones.	Greystones — *Glacial drift.* — In the washings of the sea-cliffs to the northward of the village; associated with black magnetic sand.
,,	8	Bray Head.	Bray—*Cambrian.*—Particles in a small quartz vein, discovered by *Francis Codd.*
Wicklow and Kildare.		Liffey and Slaney Valleys.	*Diluvium.*—According to the Annals, gold "placers" were worked in the valley of the Liffey, and probably also in the valleys of the head waters of the Slaney. The river systems of the Slaney and Liffey have changed from what they were originally; as at one time the Liffey occupied the valley from Ballymore-Eustace to Baltinglass, and joined there into the Slaney valley. This change cannot have been at a very distant period. The Slaney also at one time seems not to have gone through the Granyte range; but at Tulla to have gone south-westward. This, however, was a much earlier change, as the river was banked into its present course by the "Esker sea gravel." The ancient workings are supposed to have been somewhere near Ballymore-Eustace. Places that gold might be looked for are: in Glenimale and the other head valleys of the Slaney; and in the ancient river course of the Liffey between Ballymore-Eustace and Baltimore.

TIN.

COUNTIES.	No. of Ordnan'e Sheet.	LOCALITIES.	REMARKS.
Dublin.	23	*Dalkey.*	Kingstown—*Granyte.*—With lead and zinc. The mine worked for the lead. The only place in Ireland where tin is at present known to have occurred as an ore in a lode. It is reported to have been found at Kilcrohane (Sheep Head), Co. Cork, but the find has not been authenticated.
Kerry.		Lough Leane (?)	Killarney—*Devonian ?*—Although tin has not been found here in recent years, Nennius, writing in the ninth century, *Historia Britonum*, mentions tin, lead, iron, and copper, as occurring in this vicinity. All of these except the tin have since been found and profitably worked. Smith, in his *Natural History of Kerry*, states he found an ore containing tin near the lake, but does not give particulars.
Wicklow.	40	*Goldmine River.*	Woodenbridge — *Diluvium.* — With stream-gold and magnetic sand. In this locality there is possibly a lode containing the tin, but it has still to be discovered. [*See* "On the Possibility of Gold being found in the Co. Wicklow," *Sci. Proc. Royal Dublin Society*, February, 1883.]

NATIVE SILVER.

[In the following lodes and localities, native silver has been found, but only in small quantities. Silver-lead (*argentiferous galenite*) occurs in numerous other places, and in a few places silver-copper (*argentiferous chalcopyrite*)] :—

COUNTIES.	No. of Ordnan'e Sheet.	LOCALITIES.	REMARKS.
Clare.	35	*Milltown.*	Tulla—*Carboniferous.*—Ancient lead mine, in which were found stone and wood implements. NOTE.—A "silver mine" is recorded in James I.'s time "adjacent to the O'Loughlin Castle," in the barony of Burren. The ore, however, was probably silver-lead.

Counties.	No. of Ordnan'e Sheet.	Localities.	Remarks.
Cork.	147	*Boulysallagh.*	Crookhaven — *Devonian.* — Associated with lead and copper ores.
Dublin.	26	*Ballycorus.*	Goldenball—*Granyte.*—With lead ore. A large piece was accidentally put into the smelting-pot with the lead ore, and the silver ran into the brick-work of the furnace (*Kane*).
Galway.	122	*Caherglassen.*	Gort—*Carboniferous.*—With lead ore. Pieces said to have been of a fair size.
,,	107 and 117	*Carhoon* (?)	Tynagh—*Carboniferous.*—A very ancient mine, possibly one of the silver mines mentioned in the early Annals.
Kerry.	30	*Lissooleen.*	Tralee — *Carboniferous.* — Threads and particles of silver in the lead ore.
,,	30	*Clogher.*	Castleisland—*Carboniferous.*—Threads of silver in the lead ore.
Kilkenny.	32	*Ballygallion.*	Inistioge—*Carboniferous.*—A very ancient mine, supposed to be the Argetros (*Silverwood*) of the Annals, when silver shields were made, A.M. 3817.
Leitrim.	7	*Twigspark.*	Lurganboy — *Carboniferous.* — In minute specks and strings in the lead ore.
Limerick.	11	*Ballysteen* or Ballycanauna.	Askeaton—*Carboniferous.*—Thread of silver in the lead ore.
Sligo.	20	*Abbeystown.*	Ballysodare — *Carboniferous.* — Strings and particles in lead ore.
Tipperary.	22	*Garrane.*	Toomavara.—*Carboniferous.*—Adjoining the mearing of Kilnafinch there is a very ancient mine, supposed to be the Rosargid (*Silverwood*) of the Annals.
,,	26	*Silvermines.*	Nenagh—*Carboniferous.*—Very ancient mine. In these mines and the newer mines to the westward at Shallee, native silver associated with lead, and in some lodes with copper.
,,	26	*Shallee.*	
Wicklow.	35	*Cronebane.*	Ovoca—*Ordovician.*—Associated with the lead ore of the Gossan lodes, and with the Kilmacooite. *See Lead ore List.*
,,	35	*Connary.*	
,,	35	*Kilmacoo.*	

LEAD AND ZINC.

[Except in a few localities the ores of zinc are accompanied by those of lead. In many places are found more or less grouped together the sulphides of lead (*galenite*), zinc (*blende* or *sphalerite*), and iron (*pyrite* or *sulphur ore*), and more seldom the sulphides of copper (*chalcopyrite*), arsenic (*arsenopyrite* or *mispickel*), and antimony (*stibnite*), with the sulphate of baryta (*barite*). The lead ore is often argentiferous, and in a few places the copper ore. In some places are found the carbonates of lead (*cerussite*), zinc (*calamine*), and copper (*malachite*), also the silicate of zinc (*Smithsonite*).]

COUNTIES.	No. of Ordnance Sheet.	LOCALITIES.	REMARKS.
Armagh.	25	*Carrickgallogly.*	Belleek—*Ordovician.*—Lead.
,,	25	*Drumnahoney.*	
,,	28	*Dorsay.*	Crossmaglen—*Ordovician.*—Principally lead.
,,	31	*Tullyard.*	
,,	19	*Clay.*	Keady—*Ordovician.*—Principally lead. At Clay there is also manganese. At Carryhugh Glen there are two silver-lead lodes, called the *Red* and *Blue lodes;* the first being in a ferriferous stuff, and the other is a bluish flucan.
,,	19	*Doohat*, or *Crossreagh.*	
,,	19	*Drummeland*, or *Derrynoose.*	
,,	19	*Carryhugh.*	
,,	19	Darkley.	
,,	19	Tullyhawood.	
,,	15	Tamlaght.	Middletown—*Ordovician.*—Lead.
,,	22	*Drumbanagher*, or Church Glen.	Newry—*Ordovician.*(?)—Lead.
,,	25	Ballintemple.	Newtownhamilton—*Ordovician.*—Lead.
,,		Finiskin.	Cullyhanna—*Ordovician.*—Lead.
,,	22	*Kilmonaghan.*	Goragh Wood (Gerrard's Pass)—*Ordovician.*—Lead.
,,	18(?)	*Ballymore.*	Poyntzpass—*Ordovician.*(?)—An ancient mine; its exact site being now undetermined.—(*Griffith.*)
Cavan.	22	*Cornanurney.*	Cootehill—*Ordovician.*—Lead and silver-lead.
,,	22	Cloghstrukagh.	
,,	22	Drumfaldra.	
,,	29	Shercock.	South-east of . . —*Ordovician.*—Lead.
,,	10	*Ortnacullagh* (Ballyconnell).	Belturbet—*Carboniferous.*—Silver-lead.
Clare.	6	*Cappagh.*	Ballyvaughan—*Carboniferous.*—At Cappagh there are silver-lead, copper, and manganese. At Sheshodonnell only carbonate of zinc, which occurs in botryoidal masses. At Lisnauroum copper is associated with the lead: while in the other localities lead only is recorded.—*See note, Native silver, Co. Clare.*
,,	6	*Moneen.*	
,,	6	*Ailwee.*	
,,	6	*Mogoahy.*	
,,	6	Glencrawne.	
,,	6	*Sheshodonnell.*	
,,	8	Lough Aleenaun.	
,,	9	Lisnauroum.	
,,	8	*Doolin Castle.*	

Counties.	No. of Ordnan'e Sheet.	Localities.	Remarks.
Clare.	19 & 27	Glendree.	Feakle—*Ordovician.*—Lead.
,,	34	*Carrownakilly.*	Newmarket-on-Fergus—*Carboniferous.*—At the first the ore was silver-lead, while at the second it was associated with sulphur ore.
,,	42 & 51	Rathlaheen West.	
,,	51	Newmarket.	
,,	34	*Ballyhicky.*	Quin—*Carboniferous.*—Pockets of lead-ore occurred at these places; they are now worked out. They consisted principally of silver-lead. At Monanoe, or Kilbreckan, the peculiar mineral called Kilbreckanite was found, in which lead and antimony were mixed in such proportions as those used for printers' type.
,,	34	*Castletown.*	
,,	34	*Moyreisk.*	
,,	34	*Monanoe,* or Kilbreckan.	
,,	26	*Ballyvergin.*	Tulla—*Carboniferous.*—Silver-lead principally. At Ballyvergin there was also copper and sulphur ore. At Milltown, a very ancient mine, native silver occurred; while at Carrahin tumblers only have been found. The deposits in general seem to be worked out; but near Ballyvergin and Milltown are untried calcspar veins.
,,	34	*Knockaphreaghaun.*	
,,	35	*Milltown.*	
,,	35	*Carrahin.*	
,,	4	*Crumlin.*	Broadford—*Ordovician.*—Supposed to be worked out—silver-lead principally.
,,	8	*Doolin.*	
,,		*Ballykelly.*	
,,	51	Rathlaheen South.	Sixmilebridge—*Ordovician.*—Lead and sulphur ore. Tumblers of lead were found at Gallows Hill, close to the western continuation of the great fault of Silvermines, Co. Tipperary.—*See list, Co. Tipperary.*
,,	43	Knocksnaghta.	
,,	27	*Ballyhurly.*	Tomgraney—*Ordovician.*—Principally lead.
,,	29	Cahir.	
,,	29	Ballynagleragh.	
Cork.	127	*Kilkinnikin.*	Bearhaven—*Carboniferous Slate*—Lead. In the latter townland traces of lead and copper in different places.
,,	115 &c.	Killaconenagh.	
,,	118	*Gortacloona.*	Bantry—*Carboniferous Slate.*—Silver-lead, silver-copper (*grey copper ore*), iron (*chalybite*), copper, and arsenic.
,,	117	*Killoveenoge.*	
,,	117	*Rooska.*	
,,	117	*Lissaremig.*	
,,	140	*Ballycummisk.*	Ballydehob—*Yellow Sandstone,* or *Devonian.*—Lead and copper. At Ballycummisk, also barytes.—*See Copper list.*
,,	140	*Kilkilleen.*	
,,	140	*Leheratanvalley.*	

COUNTIES.	No. of Ordnan'e Sheet.	LOCALITIES.	REMARKS.
Cork.	144	*Coosheen.*	Skull—*Yellow Sandstone*, or *Devonian.*—Lead, copper, and iron.
,,	147	*Boulysallagh.*	Crookhaven—*Yellow Sandstone*, or *Devonian.*—Lead and copper. Silver-lead and silver at Boulysallagh.
,,	147	*Kilmoe* (Spanish Cove).	
,,	133 & 134	*Cooladerreen.*	Leap—*Carboniferous Slate*—Silver-lead.
,,	142	Rabbit Island.	Castletownsend—*Yellow Sandstone*, or *Devonian.*—Lead, antimony, and copper.
,,	144	*Duneen.*	Clonakilty—*Carboniferous Slate.*—Lead, barytes, and copper. Worked principally for barytes.
,,	99	*Ringabella.*	Nohaval—*Carboniferous Slate.*—Silver-lead and lead.
,,	99	*Minane.*	
,,	75 & 76	*Carrigtohill.*	Vicinity of . . —*Carboniferous Slate.*—Lead and zinc.
Donegal.	106	Bundoran.	Vicinity of . . —*Carboniferous.*—Lead and copper traces.
,,	107	*Abbey Island.*	Ballyshannon—*Carboniferous.*—At the first three, silver-lead, zinc, and copper; at the others principally lead. At Carricknahorna also iron; worked in 1883.
,,	107	*Abbey Lands.*	
,,	107	*Finner.*	
,,	103	*Ballymagrorty.*	
,,	103	Carricknahorna.	
,,	107	*Tonregee.*	
,,	68	*Welshtown.*	Ballybofey—*Metamorphic Ordovician*(?)—Lead and iron.
,,	20	*Carrowmore*, or *Glentogher.*	Carndonagh—*Cambrian*, or *Ordovician.*—Silver-lead, zinc, and sulphur ore.
,,	17	Fanad.	Glinsk—*Cambrian.* (?)—Lead and copper traces.
,,	26	Drumreen.	Carrigart—*Cambrian.*(?)—Lead.
,,	16 & 26	Ards.	Dunfanaghy—*Cambrian*, or *Ordovician.*—Lead, copper, and sulphur ore. Except at Ards, the lodes were worked out by the Mining Co. of Ireland.
,,	33	*Keeldrum.*	
,,	15	*Marfagh.*	
,,	74	*Drumnacross.*	Glenties—*Ordovician.*—Lead, zinc, and sulphur ore; but principally lead. In Scraig Mountain traces of lead and copper.
,,	66	*Fintown*, Loughnambreddan.	
,,	65 &c.	Gwebarra River.	
,,	74	*Kilrean.*	
,,	74	*Mullantiboyle.*	
,,	66 & 67	Scraig Mountain.	

Counties.	No. of Ordnance Sheet.	Localities.	Remarks.
Donegal.	64	*Iniskeel.*	Naran—*Ordovician.*(?)—Lead and copper.
,,	89	*Malinbeg.*	Killybegs—*Ordovician.* (?)—Silver-lead and manganese.
,,	44	*Derryveagh* (Gartan).	*Church Hill—Cambrian.*(?)—Lead.
,,	53	*Knockybrin.*	Letterkenny—*Ordovician.*—Lead at the mearing of Knockybrin and Woodquarter. Further northward tumblers of lead in Lough Gannon.
,,	53	*Woodquarter.*	
,,	45	Lough Gannon.	
			Note.—The ages of the Metamorphic Rocks in north and west Donegal are undetermined; they are probably Ordovicians and Cambrians.
Down.	53	Glasdrumman.	Annalong—*Ordovician.*—Lead and copper.
,,	45	Ardtole.	Ardglass—*Ordovician.*—Lead. At Gun's Island, also, copper and barytes.
,,	39	Gun's Island.	
,,	48	*Fofanny.*	Bryansford—*Ordovician.*—Lead.
,,	55	Leitrim.	Kilkeel—*Ordovician*, and *Granyte.*—Lead with, in places, copper.
,,	52 &c.	*Mourne Mountains.*	
,,	44	Ballydargan.	Killough — *Ordovician.* — Lead, with barytes at Rathmullen.
,,	45	*Killough.*	
,,	45	*Rathmullan.*	
,,	45	*Rathdrum.*	
,,	43	*Moneylane.*	Dundrum — *Ordovician.* — Principally lead.
,,	43	*Wateresk.*	
,,	31	*Corporation.*	Killyleagh—*Ordovician.*—Lead.
,,	31	*Tullyralty.*	Strangford—*Ordovician.*—Lead and copper; also zinc at Castleward.
,,	31	Castleward.	
,,	21	Dromore.	Vicinity of . . —*Ordovician.*—Lead and manganese.
,,	6	*Whitespots* (Conlig).	Newtownards—*Ordovician.*—Lead. A peculiar lode. A highly metalliferous whinstone dyke, so rich with lead that it could be profitably worked as an ore.
,,	1	Ballyleidy.	Crawford's burn—*Ordovician.*—Lead.

COUNTIES.	No. of Ordnan'e Sheet.	LOCALITIES.	REMARKS.
Dublin.	14 & 18	Ashtown.	Dublin—*Carboniferous Limestone (Calp division)*.—Lead was the principal ore, except at Dolphin's Barn, where there was also zinc. The lodes at the places printed in italics are supposed to be worked out.
"	17	*Castleknock.*	
"	14	*Cloghran.*	
"	19	*Clontarf.*	
"	19	*Killester.*	
"	22	Crumlin.	
"	18	*Dolphin's Barn.*	
"	13 & 17	Kellystown.	
"	18	Kilmainham.	
"	18	Phœnix Park.	
"	26	*Ballycorus.*	Golden Ball—*Granyte.*—Here are situated the lead-reducing works of the Mining Company of Ireland: the lead lode is said to be worked out. Native silver found here.—*See Native silver.*
"	26	*Rathmichael.*	Golden Ball—*Granyte.*—Lead: said to be worked out.
"	26	*Shankhill.*	
"	16	*Howth.*	Vicinity of . . —*Cambrian.*—Lead: worked out.
"	23	*Dalkey.*	Kingstown — *Granyte.*—Worked out. Zinc and tin associated with lead ore. In no other place in Ireland, in modern times, has tin, as an ore, been found in a vein.—*See Tin list.*
"	23	*Mount Mapas.*	Killiney Hill—*Ordovician.*—Copper and lead: worked out.
Fermanagh.		*Magheramenagh.*	Belleek—*Carboniferous.*—Lead in small quantities: worked about 1872.
Galway.	117	*Crannagh.*	Tynagh — *Carboniferous.* — Principally lead. For the works at Carhoon, *see Native silver list.*
"	107 & 117	*Carhoon.*	
"	117	Quarry Hill.	
"	113	*Ballymaquiff.*	Ardrahan—*Carboniferous.*—The paying portions of the known veins are worked out. Lead associated with copper at Muggaunagh.
"	103	*Muggaunagh.*	
"	103	*Parkatleva.*	

Counties.	No. of Ordnance Sheet.	Localities.	Remarks.
Galway.	122	*Caherglassaun.*	Gort—*Carboniferous.*—A rich lode, silver, and silver-lead. A large mass of the latter was exhibited at the Dublin Exhibition, 1851. Unfortunately, on account of the cavernous nature of the limestone, the tide's ebb and flow affect the water of the mine, and prevent the deep ore from being followed.
,,	103	Killeely.	Kilcolgan—*Carboniferous.*—Lead.
,,	94	*Rinvile West.*	Oranmore—*Carboniferous.*—Lead and zinc.
,,	94	*Cappanaveragh* (Lenaboy).	Galway—*Granyte.*—Lead.
,,	92	Spiddal West.	Spiddal—*Granyte.*—Lead, copper, and sulphur ore. At Minna there is a fair show of copper.
,,	92	*Kilroe West.*	
,,	91	*Inverin and Minna.*	
,,	91	Tully.	
,,	90	*Rossaveel.*	Costelloe, or Cashla Bay.—*Granyte.*—Principally lead; copper at Derrynea and Rossaveel. In the Carrowroe promontory, bearing about N.N.E. and S.S.W., is a large reef of quartz that, in places, has a slight mineral staining.
,,		*Derroogh South.*	
,,	90	Booroughaun.	
,,	90	Keeraunbeg.	
,,	90	*Carrowroe south.*	
,,	78	Clynagh (Crumpaun).	
,,	78	*Lettermuckoo* (Carrafinla).	
,,	79	*Derrynea* (Loughaunweeny).	
,,	11	Leenaun (Benwee).	Leenaun—*Silurian.*—Lead and silver-lead; also barytes at Griggins.
,,	25	Griggins.	
,,	36	Derrylea.	Clifden—*Metamorphic Cambrian* and *Ordovician.*—At Derrylea there was a large excavation in search of gold, not a particle of which was found.
,,	36	Bamanoran.	
,,	49	Lettershask Lough.	
,,	50	Roundstone.	Vicinity of .. —*Granyte.*—Lead.
,,	54	*Claremount.*	Oughterard—*Carboniferous.*—Lead: principally.
,,	54	*Tonweeroe.*	
,,	54	*Ardvarne.*	
,,	54	Illaun-na-creeva.	
,,	54	Moyvoon East.	
,,	54	*Lemonfield.*	
,,	54	Eighterard.	
,,	54	*Cregg.*	
,,	54	*Portacarron.*	

COUNTIES.	No. of Ordnan'e Sheet.	LOCALITIES.	REMARKS.
Galway.	39	Barnagorteen.	Oughterard—*Metamorphic Cambrian* and *Ordovician, with intrudes of Granyte,* &c.—Where the rock is limestone or granyte the ore is principally lead; but elsewhere lead, copper, zinc, barytes, and sulphur ore occur more or less together. At Glengowla East the gangue in part was crystalline green fluorspar.
,,	39	*Curraghduff North, Middle* and *South.*	
,,	39	*Derroura.*	
,,	39	*Barratleva.*	
,,	54	Rusheeny.	
,,	54	*Canrawer.*	
,,	54	*Cregg.*	
,,	54	*Clooshgereen.*	
,,	54	*Glengowla East.*	
,,	64	,, *West.*	
,,	55	*Corraneilistrum.*	Moycullen—*Carboniferous.*—Principally lead. The Wormhole mine is alongside Lough Corrib, and it is difficult to keep the water down, as there is leakage from the lake.
,,	68	*Gortmore* (Wormhole).	
,,	39	Drumsnauv (Doon).	Maum Bridge—*Metamorphosed Ordovician.*—Lead, copper, manganese, and iron.
,,	39	Carrowgarriff.	
,,	55	Curraghmore.	Headford—*Carboniferous.*—Lead and sulphur ore.
,,	85	Knockroe.	Monivea—*Carboniferous.*—Lead.
Kerry.	20 & 21	*Ardfert.*	Vicinity of . . —*Carboniferous.*—Lead.
,,	30	*Clogher.*	Castleisland — *Carboniferous.* — Silver, silver-lead, and copper.
,,	47	*Annagh East.*	Castlemaine — *Carboniferous.* — Silver-lead; with zinc at Annagh, and a little copper at Meanus.
,,	47	*Meanus.*	
,,	47	Ballybrack.	
,,	9	Ballinglanna.	Causeway—*Carboniferous.*—Lead; with a little copper on the coast to the east of Cashen River.
,,	9	East of Cashen River.	
,,	15 & 16	Lixnaw.	
,,	93	*Caher West*, or Shanagarry.	Kenmare — *Carboniferous.*—Lead. At Shanagarry, a sub-division of Caher West, silver-lead and copper are associated.
,,	93	*Killowen.*	
,,	93	Public Garden.	
,,	66	*Cahernane.*	Killarney— *Carboniferous.*— Silver-lead at Cahernane. Lead, zinc, and copper at Ross Island.
,,	66	*Ross Island.*	
,,	29	Ballybeggan.	Tralee — *Carboniferous.* — At Oakpark only lead is recorded; at the others copper was associated with silver-lead. Native silver at Lissooleen.
,,	29	Ballymullen.	
,,	30	*Lissooleen.*	
,,	29	Oakpark.	
Kildare.	15	Ardclogh.	Celbridge—*Carboniferous.*—Lead; with some zinc at Wheatfield.
,,	15	Wheatfield Upper.	

Counties.	No. of Ordnance Sheet.	Localities.	Remarks.
Kildare.	3	*Freagh.*	Edenderry — *Carboniferous.* — Lead: worked out.
Kilkenny.	32	*Ballygallon.*	Inistioge—*Carboniferous.*—Silver-lead.
,,	43	Dunkitt.	Kilmacow—*Carboniferous.*—Lead.
,,	27	*Knockadrina* (Flood Hall).	Knocktopher — *Carboniferous.* — Silver and silver-lead; a very ancient mine. *See Native silver list.*
King's Co.	12	*Monasteroris* (*Blundell Mines*).	Edenderry — *Carboniferous.* — Lead: worked out.
,,	36 &c.	Slieve Bloom.	Kinnity—In the *Ordovician* rocks of Slieve Bloom, lead and copper have been recorded in several places, but whether together or separate is not mentioned.
Leitrim. ,,	11 7	Barrackpark. *Twigspark.*	Lurganboy — *Carboniferous.* — Silver-lead in dolomitic sand.
Limerick. ,, ,, ,,	11 28 11 28	*Ballycanauna,* or *Ballysteen.* *Graiguelough.* Askeaton. *Kilcolman.*	Askeaton—*Carboniferous.*—Lead; with some zinc and pyrites at Graigue; at Ballysteen there was silver-lead and silver. The known deposits in these places, except Askeaton, worked out.
,,	3	*Ballydoole.*	Pallaskenry — *Carboniferous.* — Copper and silver-lead.
,, ,, ,, ,, ,, ,,	20 20 20 20 20 20	Ardgoul South. Freagh. Boolaglass. *Ballingarrane.* *Cloghatrida.* *Ballinvirick.*	Rathkeale—*Carboniferous.*—At Ardgoul —discovered when making the railway—there is a good show of silver-lead. Freagh and Boolaglass unproved. The other places, where there was silver-lead, zinc, copper, and pyrites, are worked out.
,,	36	*Mahoonagh.*	Newcastle — *Carboniferous.* — Lead: worked out.
,,	25	Tower Hill.	Pallasgreen—*Carboniferous.*—Lead.

COUNTIES.	No. of Ordnance Sheet.	LOCALITIES.	REMARKS.
Limerick.	25	*Oola Hill.*	Oola—*Carboniferous.*—Silver-lead, carbonate of lead, copper, and barytes.
,,	25	Carrigbeg, or Coonagh Castle.	Doon—*Carboniferous.*—Lead.
Londonderry.	25	Scriggan.	Dungiven — *Carboniferous.*—Tumblers and fragments of lead (*galenite*).
Longford.	14	Longford.	Two miles E.S.E. of . . —*Carboniferous.* —Silver-lead.
Louth.	23 & 24	Oldbridge.	Drogheda—*Ordovician.*—Lead and copper.
,,	7	Crumlin.	Dundalk—*Ordovician.*—Lead. At Fairhill tumblers were found in the trials made.
,,	7	*Fairhill.*	
,,	16	*Salterstown.*	Togher—*Ordovician.*—Lead and copper.
Mayo.	103	Ballynastockagh, or Bellaveel.	Ballyhaunis—*Carboniferous.*—Lead.
,,	75	*Bolinglana.*	Newport—*Carboniferous.*—Silver-lead, copper, and pyrites.
,,	65	*Srahmore.*	
,,	107	*Tawneycrower* (Sheefry).	Westport—*Ordovician.*—Silver-lead.
,,	121	Ballymacgibbon.	Headford — *Carboniferous.*—Lead and pyrites.
,,	121	Gortbrack.	
Meath.	33	*Cloghan.*	Ardcath—*Ordovician.*—Lead; very ancient mine.—(*Griffith.*)
,,	29 & 35	*Athboy.*	South of . . —*Carboniferous.*—Lead.
,,	26	Dollardstown.	Slane (Beaupark mine)—*Carboniferous.* —Lead and copper.
Monaghan.	19 & 24	Corbrack.	Ballyboy — *Ordovician.* —Principally lead.
,,	19	Cornamucklagh North.	
,,	19	,, South.	
,,	19	*Dernaclug.*	
,,	14	*Derrylush.*	
,,	24	Sra.	
,,	8	*Derryleedigan–Jackson.*	Bellanode— *Carboniferous.*—Lead and zinc.
,,	25	*Cornalough.*	Castleblayney—*Ordovician.*—Lead, or silver-lead; barytes at the first two. The deposits are supposed to be worked out.
,,	25	*Cleggan.*	
,,	25	*Carrickagarvan.*	
,,	25	*Dromore.*	

Counties.	No. of Ordnan'e Sheet.	Localities.	Remarks.
Monaghan.	15	*Annaglogh.*	Monaghan—*Ordovician.*—Lead is the principal ore at these localities; it being associated with zinc at Avalreagh, Kilcrow, and Coolartragh. barytes also occurring at the latter, At Lisglassan and Tullybuck it was accompanied by antimony ore. At most of the places printed in italics the paying portions of the veins were taken out.
,,	19	Annayalla.	
,,	14	Avalbane.	
,,	14	*Avelreagh.*	
,,	14	*Carrickaderry.*	
,,	14	Carrickanure.	
,,	14	*Clareoghill.*	
,,	14	*Coolartragh.*	
,,	14	Cornamucklagh North.	
,,	14	Croaghan.	
,,	14	Crossmore.	
,,	14	Glassdrumman East.	
,,	14	Grig.	
,,	14	Kilcrow.	
,,	14	Latnakelly.	
,,	14	*Lemgare.*	
,,	15	*Lisdrumgormly.*	
,,	14	*Lisglassan.*	
,,	14	*Tassan.*	
,,	14	Tonnagh.	
,,	14	*Tullybuck.*	
Queen's Co.	18	Dysart.	Maryborough—*Carboniferous.*—Lead.
,,	32	Coolbaun.	
,,	32	Ballickmoyler.	Ballickmoyler—*Carboniferous.*—Lead.
Roscommon.		—	——
Sligo.	20	*Abbeystown.*	Ballysadare—*Carboniferous* and *Cambrian.*(?)—Lead. Native silver at the first: the old deposits in both places worked out. New veins since discovered.
,,	20	*Lugawarry.*	
,,	6 & 9	*Glencarbury.*	King's Mountain, Sligo—*Carboniferous.*—Lead, copper, and barytes. The deposit at Glencarbury is principally barytes.
,,	9	Tormore.	
		Seafield (Knocknarea),	
Tipperary.	22	*Garrane.*	Toomavara — *Carboniferous.* — Locally called the "Silver mine;" supposed to be the Rosargid of the "Annals."—*See Native silver list.*
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,,			
,,	19	Corbally.	Portroe — *Ordovician.*—Lead. Garrykennedy was a very ancient mine, stone and wood implements, &c., having been found in the "Old Men's Workings."
,,	13	*Garrykennedy.*	
,,	19	Laghtea.	
,,			
,,			

COUNTIES.	No. of Ordnan'e Sheet.	LOCALITIES.	REMARKS.
Tipperary.	33 & 34	Cooleen.	Borrisoleigh—*Ordovician.*—Lead.
,,	26	*Ballygowan.*	Silvermines, near Nenagh—*Carboniferous* (sandstone and limestone).—These are all sub-denominations of the great "SILVERMINE SETT." In these mines have been found silver, silver-lead, lead, silver-copper, copper, zinc, and pyrites. They were worked in prehistoric times, and the attals in the old stulls have lain so long that, by chemical change, new minerals have formed. The fault at Silvermines, on which the lodes are situated, can be traced eastward to Toomavara, and westward to Gallowshill, near Sixmilebridge, Co. Clare.
,,	26	*Cloonanagh.*	
,,	26	*Cooleen.*	
,,	26	*Garryard East* and *West.*	
,,	26	*Gorteenadiha*, or *Gortnadyne.*	
,,	26	*Gortshaneroe*, or *Ballynoe.*	
,,	26	*Knockanroe.*	
,,	26	*Lacka.*	
,,	26	*Shallee East* and *West.*	
,,	74	*Aherlow Vale.*	Tipperary—*Carboniferous.*—Silver-lead, copper, and manganese.
Tyrone.	18(?)	*Crockanboy.*	Gortin—*Ordovician.* (?)—Lead; worked in 1854.
,,	18(?)	*Teebane West.*	
Waterford.	24	*Ballydowane.*	Bunmahon — *Ordovician.* — These are portions of "BUNMAHON COPPER MINES." At both places there was silver-lead associated with copper; while at Knockmahon zinc and cobalt were also found.—*See Copper list.*
,,	25	*Knockmahon.*	
,,	7	Monminane.	Carrick-on-Suir—*Ordovician.* (?)—Lead.
,,		Cruack.	Tramore—*Ordovician.*—An ancient lead mine.
,,	39	Mine Head.	Ardmore—*Yellow Sandstone*, or *Devonian.*—Silver-lead.
,,	40	Monatray.	Coast opposite Youghal—*Carboniferous* (?)—Lead.
,,	29	*Camphire.*	Lismore—*Carboniferous.*—Silver-lead; worked about the year 1825.
Westmeath.		—	Traces of lead found in different places.

Counties.	No. of Ordnance Sheet.	Localities.	Remarks.
Wexford.	45	*Clonmines.*	Carrick-on-Bannow.—*Ordovician.*—At Clonmines there is the *debris* of very ancient mines, supposed to have been worked by the Ostmen. Here in Charles I.'s time there was a mint. At Barrystown there were workings on a lode containing silver-lead and zinc.
,,	45	*Barrystown.*	
,,	46	Gibberpatrick.	Duncormick — *Carboniferous.* — Lead; veins of dolomite sand with strings of lead.
,,	42	Killian.	Wexford — *Carboniferous.*— Lead and barytes veins cut in the canal at the South Slob. Strings of lead found when sinking the well at Bishopswater Distillery.
,,	43	South Slob, intake.	
,,	37	Bishopswater.	
,,	19	Aughathlappa.	Enniscorthy — *Ordovician.* — Lead, or silver-lead. At Caim there were also some zinc, copper, iron, and sulphur ore. The profitable portion of the veins are supposed to be worked out.
,,	19	Caim.	
,,	19	Killoughrum.	
,,	19	Mangan.	
Wicklow.	12 &c.	*Douce Mountain.*	Enniskerry—*Granyte and Mica-schist.* —Lead and copper.
,,	7 &c.	*Powerscourt.*	
,,	9	*Glen of*	Hollywood—*Metamorphic Ordovician.*—Lead.
,,	12	*Lough Tay.*	Togher, or Roundwood—*Granyte*—Lead, with at Lough Dan copper and zinc. At Carrigeenduff, Lough Dan, the vein worked out.
,,	17	*Lough Dan.*	
,,	27	Boleylug, or Moatamoy.	Baltinglass—*Granyte,* or *Mica-schist.*—Lead.
,,	43	Shillelagh.	Vicinity of . . —*Granyte.*—Lead.
,,	38	*Carrigroe.*	Tinahely—*Granyte.*—Lead. An ancient mine.
,,	17	*Brockagh.*	Glendalough Lead Mines.—*Granyte and Mica-schist.* — Luganure and Glendassan are sub-denominations of Brockagh. Lead, silver-lead, zinc, iron, a little copper, &c.
,,	23	*Lugduff.*	
,,	17 & 23	*Camaderry.*	

COUNTIES.	No. of Ordnance Sheet.	LOCALITIES.	REMARKS.
Wicklow.	22	Lugnaquillia (North Prison).	Rathdrum, GLENMALURE MINES—*Granyte*—Extending in places into the *mica-schist*. All are in Glenmalure, the valley of the Avonbeg. In many places with the lead there are zinc and copper. At Baravore there is superior barytes, and at Clonkeen iron and zinc. At the North Prison, Lugnaquillia, there is a promising-looking lode, but the place is very inaccessible.
,,	23	*Ballinafunshoge.*	
,,	22 & 23	*Ballinagoneen.*	
,,	23	Ballyboy.	
,,	23	*Baravore.*	
,,	22	Camenabologue.	
,,	23	*Clonkeen.*	
,,	22	Clonvalla.	
,,	23	*Corrasillagh.*	
,,	23	*Cullentragh Park.*	
,,	35	Ballinaclash.	
,,	28	*Aghavannagh.*	Aughrim—*Granyte.*—Lead and copper.
,,	40	*Ballintemple.*	Woodenbridge — *Metamorphic Ordovician.*—Lead. At Clonwilliam only strings have been found.
,,	40	Clonwilliam.	
,,	35	*Shroughmore.*	Ovoca — *Metamorphic Ordovician.* —These belong to the EAST OVOCA MINES In all of them the lead is more or less associated with copper and pyrites. Native silver (auriferous) has been found in east Cronebane (Magpie), Connary, and Kilmacoo; also the peculiar mineral called Kilmacooite, or "Bluestone," which is a mixture of the sulphides of copper, lead, zinc, iron, antimony, arsenic, and silver, with a trace of gold.
,,	35	*Kilmacoo.*	
,,	35	*Connary.*	
,,	35	*Cronebane.*	
,,	35	Kilmacrea.	Redcross — *Metamorphic Ordovician.*—Zinc and lead.

COPPER.

[Copper is recorded as having been found native in the mines at East Cronebane and Connary in cracks or slight shrinkage fissures in the veins, while the mine water has deposited it on the metals in the old working. Native copper, sometimes in geodes, was found at Kilduane, Bonmahon, Co. Waterford, and sparingly in some of the lodes in S.W. Cork. Yellow copper ore (*chalcopyrite*) is often found associated with lead in the limestones of Carboniferous age, but usually in too small quantities to be of any value. In the sandstones, whether high up or at the base (*Lower Carboniferous sandstone*), the copper usually predominates. In the Devonian rocks it principally occurs as the yellow ore (*chalcopyrite*), and grey ore (*tetrahedrite*); and on the backs (*gossan lodes*) of some of the lodes, the carbonates (*malachite* and *azurites*), and oxide (*melaconite*). Generally it is only associated with sulphur ore or mundic (*pyrite*); but sometimes lead (*galenite*) and barytes (*barite*) are present; the latter in places being so mixed as to deteriorate or ruin the ore. The ores are most prevalent in the *Metallic Shales*, or the upper zone of the Devonians. In the unaltered Silurians, Ordovicians, and Cambrians, also in the granyte, the yellow ore, similarly as in the Carboniferous, usually occurs associated with the lead ores; but only in small quantities; while in the metamorphic rocks it is in larger quantities; sometimes being independent, but more often associated with pyrites, lead, zinc, or barytes. Some of the pyrite or sulphur ore at Ovoca was a poor ore of copper containing from 2 or 3 to 8 or 10 units; and the copper in the ash of such ores, after the sulphur is abstracted, is found to be remunerative.

At Carrigacat and Kilcrohane, Co. Cork, and Ballymurtagh, Co. Wicklow, the copper ore (*coppery pyrite*) is in part auriferous, while most of the old coppery lodes in the great Ovoca channel probably contained some gold. At Garryard, Gortnadyne, and Gortshaneroe, Co. Tipperary, and near Bantry, Co. Cork, the copper ores are argentiferous.]

Counties.	No. of Ordnance Sheet.	Localities.	Remarks.
Armagh.	31	Tullydonnell.	Crossmaglen—*Ordovician.*
,,	22	*Kilmonaghan* (*Gerrard's*, or *Tuscan Pass*).	Newry—*Ordovician.*
Carlow.	24 & 26	*Carricklead Mountain.*	Graiguenamanagh—*Granyte.* (?)
Cavan.	20	Farnham Demesne.	Cavan—*Carboniferous.*
Clare.	6	*Cappagh.*	Ballyvaughan — *Carboniferous.*— In small quantities with lead.
,,	6	*Glenulla.*	
,,	9	Lisnanroum.	
,,	20	Corrakyle.	Feakle—*Ordovician.*
,,	20	Leaghort.	
,,	34	*Ballyhickey.*	Quin—*Carboniferous.*—In small quantities with lead and zinc.
,,	26	*Ballyvergin.*	Tulla—*Carboniferous.*—With lead and pyrites.
,,	36 & 44	*Shannaknock.*	Broadford—*Ordovician.*—With pyrites.

COUNTIES.	No. of Ordnn'e Sheet.	LOCALITIES.	REMARKS.
Cork.	114	*Allihies.*	BEARHAVEN MINES—*Devonian.*—Yellow copper ore; with a large pocket of the carbonates in the north mine. The veins both horizontally and in depth seem to have passed out of the "metallic shales," (upper zone of the Devonians) and to have become unprofitable.
,,	127	*Cahermesleboe.*	
,,	114	*Caminches.*	
,,	114	*Cloan.*	
,,	114	*Coom.*	
,,	114 & 127	*Kealoge.*	
,,	115 &c.	Killaconenagh.	Bearhaven—*Devonian.*—With lead.
,,	90	*Esk Mountain.*	Glengariff—*Devonian.*
,,	129	*Carravilleen.*	Bantry—*Yellow Sandstone,* or *Devonian.* —At Derreengreanagh associated with barytes. At Lissaremig and Rooska grey argentiferous ore, with silver-lead, arsenic, and iron (*chalybite*).
,,	130	*Clashadoo,* or *Four-mile Water.*	
,,	117	*Lissaremig.*	
,,	117	*Rooska.*	
,,	118	*Derreengreanagh.*	
,,	129	*Glanalin.*	
,,	138	*Gortavallig.*	
,,	118	*Hollyhill.*	
,,	129	*Killeen, North.*	KILCROHANE MINES (Sheep Head)—*Yellow Sandstone,* or *Devonian.*—A large lode of sulphur-ore, with strings or thin veins of yellow copper. Along the bedding are beds containing grey copper (argentiferous and auriferous (?)), and on the back of the lodes and beds, carbonates and oxides of copper. Worked by the South Bearhaven Co. At Kilcrohane there is a thick sulphur-ore (*mundic*) lode.
,,	129	,, *South.*	
,,	129	*Knockroe.*	
,,	129	*Kilcrohane.*	
,,	140	*Ballycummisk.*	Ballydehob—*Yellow Sandstone,* or *Devonian.*—BALLYDEHOB AND AUDLEY MINES. There are different lodes in each sett, some with grey ore, others with yellow. Some of the yellow ore lodes are good, others more or less deteriorated with barytes. Lead is sometimes also found in small quantities, as at Ballycummisk, and in the gossan, at Horse Island. Skeaghanore is a peculiar name, as if gold was once found there.
,,	140	*Cappaghglass.*	
,,	140	*Foilnamuck.*	
,,	149	*Horse Island.*	
,,	140	*Rossbrin.*	
,,	140	*Ballydehob.*	
,,	140	*Boleagh.*	
,,	140	*Cooragurteen.*	
,,	140	*Kilcoe.*	
,,	140	*Skeaghanore.*	
,,	131	*Derreennalomane.*	
,,			
,,	140	*Kilkilleen.*	Ballydehob—*Yellow Sandstone,* or *Devonian.*—ROARING WATER MINES. Copper and lead.
,,	140	*Laheratanvally.*	
,,	140	*Leighcloon.*	

Counties.	No. of Ordnan'e Sheet.	Localities.	Remarks.
Cork.	148	*Castlepoint.*	Skull Mines—*Yellow Sandstone*, or *Devonian*.—Generally more than one lode in each sett. Principal ores the yellow and grey! but at Coosheen there was a back of carbonates and iron. At Mount Gabriel there is also barytes.
”	149	*Castleisland.*	
”	139 & 144	*Coosheen.*	
”	140	*Gortnamona.*	
”	148	*Longisland.*	
”	148	*Skull.*	
”	148	Leamcon.	
”	139	*Mount Gabriel.*	
”	148	Altar.	Crookhaven Mines—*Yellow Sandstone*, or *Devonian*.—Yellow and grey ores. In some setts more than one lode. At Carricat the gossan was auriferous, at Boulysallagh there were silver and lead, and at Spanish Cove silver-lead. At Balteen a quartz lode was worked for gold, although no gold had ever been detected in it.
”	147	Ballydivlin.	
”	147	Ballyrisode.	
”	147	*Balteen.*	
”	147	*Carricat*, or *Dhurode.*	
”	147	*Boulysallagh*,	
”	147	*Callaros.*	
”	146	*Cloghane* (Mizzen Head).	
”	147	*Crookhaven.*	
”	147	*Kilbarry.*	
”	152	*Mullavoge* (Brow Head).	
”	147	*Kilmore* (Spanish Cove).	
”	147	*Lackavaun.*	
”	148	*Toormore.*	
”	151	*Bawnishall.*	Skibbereen—*Yellow Sandstone*, or *Devonian*.
”	142	Rabbit Island.	Castletownsend—*Yellow Sandstone*, or *Devonian*.—Also lead and antimony.
”	142	*Aughatubrid.*	Roscarberry—(Glandore Mines) *Yellow Sandstone*, or *Devonian*.—At Aughatubrid there is a back of iron and manganese that extends eastward to Roury Glen and Roscarberry (*see list, Iron ores*). At Little Island there is barytes.
”	143	*Derry.*	
”	142	*Drom.*	
”	142	*Keamore.*	
”	143	*Kilfinnan.*	
”	143	Gortagrenane.	
”	143	Little Island.	
”	144	*Duneen.*	Clonakilty—*Yellow Sandstone*, or *Devonian*.—Also lead and barytes: the mine worked principally for the latter.
”	107	Derreens.	Dunmanway—*Devonian*, or *Yellow Sandstone*.
”	107	*Coom.*	
”	107	*Inchanadreen.*	
”	78	*Knockadoon.*	Youghal—*Devonian*, or *Yellow Sandstone*.—At the Fever Hospital there is a strong coppery-looking spa.
”	78	Capel Island.	
”	67	Fever Hospital.	
”	63 & 74	Rathpeacan.	Cork—*Yellow Sandstone*, or *Devonian*.—Yellow ore, with a little carbonate.
”	38	Millstreet.	Vicinity of . . —*Devonian*. (?)

COUNTIES.	No. of Ordnan'e Sheet.	LOCALITIES.	REMARKS.
Donegal.	106	Bundoran.	Vicinity of . .—*Carboniferous.*—Also lead.
,,	107	*Abbeyisland.*	Ballyshannon — *Carboniferous.* — With lead and zinc : worked for the lead ore.
,,	107	*Abbeylands.*	
,,	107	*Finner.*	
,,	28	Saltpans.	Rathmullen — *Ordovician.* —Thin vein yellow ore ; a quartz lode, to the northward, coppery.
,,	53 & 61	Scrably and Carrygally.	South of Letterkenny—*Cambrian.*(?)—A copper-stained quartz lode, with N.E. and S.W. line of coppery spas.
,,	4, &c.	Clonea.	Carndonagh—*Ordovician.* (?)
,,	36	Casheleenan.	Kilmacrenan—*Ordovician.* (?)
,,	15	*Marfagh.*	Dunfanaghy—*Cambrian.*(?)—Also lead, pyrites, and iron: worked for the lead principally.
,,	17	Fanad.	Glinsk—*Ordovician.*(?)—Also lead.
,,	64, &c.	Iniskeel.	Naran—*Ordovician.*(?)—Also lead.
Down.	53	Glassdrumman.	Annalong—*Ordovician.*—Also lead.
,,	39	Gun's Island.	Ardglass—*Ordovician.*—Also lead and barytes.
,,	52 &c.	*Mourne Mountains.*	Kilkeel—*Granyte* and *Ordovician.*—Also lead.
,,	45	St. John's Point.	Killough—*Ordovician.*—Also pyrites.
,,	31	*Tullyratty.*	Strangford—*Ordovician.*—Also lead.
Dublin.	23	Seapoint.	Blackrock—*Granyte.*—Traces.
,,	12	Malahide.	Vicinity of . . —*Carboniferous.*
,,	9	Lambay.	Skerries—*Ordovician.*—Also iron.
,,	5	*Loughshinny.*	Rush—*Carboniferous.*
Fermanagh.	9	*Rossbeg*, or *Castle Caldwell.*	Belleek—*Carboniferous.* (?)—Also iron. NOTE.—At Magheramenagh, between Castle Caldwell and Belleek, copper was raised by the late Mr. Johnston in the Carboniferous limestone.
Galway.	91	*Inverrin* and *Minna.*	Spiddal—*Granyte*, or *allied rocks.*—Ores very mixed; lead and pyrites usually present : which, in general, are more abundant than the copper.
,,	79	*Derrynea.*	
,,	90	*Rossaveel.*	
,,	90	*Maumeen* (Gorumna Island).	
,,	90	Teeranea.	

Counties.	No. of Ordnance Sheet	Localities.	Remarks.
Galway.	54	*Bunnagippaun.*	Oughterard—*Metamorphic Cambrians,* or *Ordovician.*—Lead, pyrites, or pyrrhotite, are generally present; sometimes zinc and barytes. If the lode is in limestone, as at Glengowla, the ore is principally lead. In the Curraghduffs there were good bunches of yellow copper ore.
,,	54	*Canrower.*	
,,	54	Creggs.	
,,	54	*Clooshgereen.*	
,,	54	*Glengowla West.*	
,,	39	*Barratleva.*	
,,	39	*Derroura.*	
,,	39	*Curraghduff— West, Middle, and South.*	
,,	39	Derreenagusfoor.	
,,	39	Curraunbeg.	
,,	39	Shannawagh.	
,,	39	Derroura.	
,,	40	*Gorteenwalla.*	
,,	40	*Ballygally.*	
,,	39	*Drumsnauv.*	Maum Bridge—*Metamorphic Cambrian.*—At Drumsnauv there were also lead, manganese, and iron; while at Maumwee the ore was principally pyrrhotite.
,,	39	*Maumwee.*	
,,	11	*Leenaun* (Benwee).	Leenaun Hotel—*Silurian.*—Principally lead.
,,	49	Ballyconneely.	Roundstone—*Metamorphic Ordovician, Granyte,* &c.
,,	50	Tallaghlummanmore.	
,,	63	*Murvey.*	
,,	63	*Dogs Bay.*	
,,	63	Errisbeg, West and East.	
,,	9	Cleggan Tower.	Clifden—*Metamorphic Ordovician,* or *Cambrian.*—In the *Rinvyle district, Dawrosmore* (*sheets* 10 and 23), *Cloonlooaun* (9 and 10), *Cashleen* (9), &c., trials have been made in search for copper and iron, but not with good result. This tract lies to the N.W. of Kylemore Lake.
,,	9	Tullymore.	
,,	21	*High Island.*	
,,	22	*Cloon* (Cleggan Mine).	
,,	22	*Boolard.*	
,,	22	*Doon.*	
,,	22	*Dooneen.*	
,,	35	*Ardbear.*	
,,	35	*Fakeeragh.*	
,,	24	Kylemore and Gleninagh.	Recess — *Metamorphic Cambrian.* (?)—Also sulphur ore.
,,	36	Barnanoran.	
Kerry.	30	*Clogher.*	Castleisland—*Carboniferous.*—With silver and lead: worked for the lead.
,,			
,,	47	*Meanus.*	Castlemaine—*Carboniferous.*—With lead: worked for the latter.
,,	9&c.	Coast east of Cashen River.	Causeway—*Carboniferous.*—With lead.
,,	52	Dunquin.	Vicinity of . .

COUNTIES.	No. of Ordnance Sheet.	LOCALITIES.	REMARKS.
Kerry.	93	*Greenlane.*	Kenmare—*Carboniferous* and *Devonian.* —With silver-lead at Caher West.
,,	93	*Cromwell's Fort.*	
,,	93 & 102	*Mucksna.*	
,,	93	*Ardtully* (Clontoo).	
,,	93	*Caher West* (Shannagarry).	
,,	93	Caher East.	
,,	84 & 93	Gortnacurra.	
,,	93	Kenmare, west of.	
,,	74	*Muckross.*	Killarney—*Carboniferous.*—Very ancient mines. Cobalt and sulphur ore at Muckross; lead and zinc at Ross Island: the latter worked principally for lead. Mines mentioned by Nennius, a ninth century writer.
,,	66	*Ross Island.*	
,,	106	*Garrough.*	Sneem—*Yellow Sandstone,* or *Devonian.*
,,	99	*Staigue.*	
,,	29	Ballybeggan.	Tralee — *Carboniferous.* — Principally lead. At Lissoleen there is native silver.
,,	29	Ballymullen.	
,,	30	*Lissoleen.*	
,,	78 & 87	Finnies Upper.	Cahersiveen—*Devonian,* or *Silurian.*
,,		Oughquick.	
,,	87	Clynacartan.	
,,	79	Garranearagh.	
,,	106	*St. Crohan,* or Behaghane.	Westcove—*Devonian.*(?)
Kildare.	17	Punchersgrange.	Newbridge—*Ordovician.*
,,	22	Dunmurray.	Kildare—*Ordovician.*
Kilkenny.	31	Knocktopher.	Vicinity of . . —*Carboniferous.*
King's Co.		*Monasteroris.*	Killan, on Grand Canal.—*Carboniferous.*
,,	36 &c.	Slieve Bloom.	Kinnity—*Carboniferous Sandstone,* and *Ordovician.*
Leitrim.		Skreeny.	Manorhamilton—*Metamorphic Cambrian.*(?)
,,	11	*Gortnaskeagh.*	Lurganboy—*Metamorphic rocks; Cambrian.*(?)
,,	11	*Pollboy.*	
,,	11	*Shanvans.*	
Limerick.	3	*Ballydoole.*	Pallaskenry—*Carboniferous.*—The mine at Ballydoole was worked for lead.
,,	3	Charter School.	

COUNTIES.	No. of Ordnance Sheet.	LOCALITIES.	REMARKS.
Limerick.	20	*Ballingarrane.*	Rathkeale—*Carboniferous.*—Also silver-lead, zinc, and sulphur ore. The deposits, which were wrought for the lead, worked out.
,,	20	*Cloghatrida.*	
,,	25	Oola Hill.	Oola—*Carboniferous.*—Also lead, zinc, and sulphur ore: the lead in excess.
Louth.	22	Clogher.	Drogheda—*Ordovician.*—Also lead at Oldbridge.
,,	23 & 24	Oldbridge, West of.	
,,	16	*Salterstown.*	Togher—*Ordovician.*—Also lead: seems to have been principally worked for the latter.
Mayo.	6	Ballydergmore.	Ballycastle—*Carboniferous.*
,,	5	Geevraun.	
,,	7	Doonadoba.	Seacoast N.E. of Ballycastle.—*Carboniferous.*
,,	86	Louisburgh.	Vicinity of . . —*Silurian.*—Also sulphur ore.
,,	114	*Bofin Island.*	Cleggan — *Ordovician.* — Also sulphur ore.
,,	75	*Bolinglana.*	Molrany, CORRAUN MINES. — *Ordovician.* (?)
,,	65	Srahmore.	
Meath.	26	Dollardstown.	Slane, BEAUPARK MINES—*Carboniferous.*—Also a little lead.
,,	26	*Painstown.*	
,,	32	*Brownstown.*	Walterstown—*Carboniferous.*—Worked in 1800: veins said to be worked out.
,,	32	*Cusackstown.*	
,,	32	*Kentstown.*	
Roscommon.	—	—	—
Sligo.	6 & 9	*Glencarbury.*	Sligo (King's Mountain)—*Carboniferous.*—Also lead; but principally barytes.
,,	9	Tormore.	
Tipperary.	33	*Gortnahalla.*	Borrisoleigh (Clodiagh Valley)—*Ordovician.*—An ancient mine.
,,	38	*Lackamore.*	Newport—*Ordovician.*—At Lackamore ancient tools were found in the "old mens'" workings.
,,	38	*Tooreenbrien Upper.*	
,,	19	Derry Demesne.	Portroe—*Ordovician.*

COUNTIES.	No. of Ordnan'e Sheet.	LOCALITIES.	REMARKS.
Tipperary.	17	*Rathnaveoge.*	Dunkerrin—*Carboniferous.*
,,	32	*Coolruntha.*	SILVERMINES, Nenagh—*Carboniferous.* —Principally in the sandstone. At the Garryards, Gorteenadiha, and Gortshaneroe there was silver-lead; the copper being also argentiferous. At Knockanroe and Shallee there was also lead, &c.—*See Lead list.*
,,	26	*Garryard East.*	
,,	26	,, *West.*	
,,	26	*Gorteenadiha.*	
,,	26	*Gortshaneroe.*	
,,	26	*Knockanroe.*	
,,	26	*Shallee East.*	
,,	26	,, *West.*	
,,	31 & 32	*Ballyhourigan.*	
,,	74	*Aherlow Vale.*	Tipperary — *Carboniferous.*—Also lead and manganese.
,,	45	*Clonmurragha.*	Cappawhite—*Ordovician.*—
,,	45	*Gleenough Upper.*	
,,	45	*Lackenacreena.*	
,,	45	*Reafadda.*	
,,	45	*Ballycohen*, or Hollyford.	
Tyrone.	37	Sluggan.	Pomeroy—*Silurian*, or *Devonian* (?)—Old working at the southern boundary of Crannogue; spas at the northern boundary. Coppery gossan at Shanmaghry and Lurganeden: more or less coppery spas in the other townlands. This country is as yet unexplored.
,,	44	Ballintrain.	
,,	45	*Crannogue* and *Knocknaclogh.*	
,,	45	Glenbeg.	
,,	45	Aghafad.	
,,	45	Shanmaghry.	
,,	45	Lurganeden.	
			NOTE.—These Tyrone rocks may in part be the representatives of the English *Lower Devonian.*
Waterford.	25	Knockane	Annestown—*Ordovician.*
,,	25	*Woodstown.*	
,,	25	*Ballydowane.*	BONMAHON MINES—*Ordovician.*—Mining in operation at an early age, as in some of the old working at the Stage lode, Knockmahon, rude stone and wooden implements were found. In this lode there were also silver-lead, zinc, and cobalt; at Ballydowane silver-lead, and at Kilduane native copper.—*See Cobalt list.*
,,	25	*Ballynagigla.*	
,,	24	*Ballynarrid.*	
,,	24 & 25	*Ballynasissala.*	
,,	25	*Kilduane.*	
,,	25	*Kilmurrin.*	
,,	25	*Knockmahon.*	
,,	25	*Tankardstown.*	
,,	24	*Templeyvrick.*	
,,	24	*Seafield.*	
,,	13	Carrigroe.	Ballynamult — *Silurian* (?) or *Devonian* (?)
,,	5	*Knockatrellane*, or *Ballymacarbery.*	
,,	32	*Killelton* (Lady's Cove).	Stradbally—*Ordovician.*
,,	24	*Kilminnin.*	

Counties.	No. of Ordnan'e Sheet.	Localities.	Remarks.
Waterford.	17	Ballykinsella.	Tramore—*Ordovician.*
Westmeath.	—	——	Traces of copper and lead in places. (*Lewis.*)
Wexford.	46	St. Tenants.	Duncormick—*Carboniferous Sandstone.*
,,	41 & 42	Forth Mountain.	Wexford—*Cambrian.*—Also sulphur ore.
,,	42	Kerlogue.	Wexford—*Carboniferous.* — Malachite.
,,	19	*Caim.*	Enniscorthy—*Ordovician.*—Silver-lead, zinc, iron, and sulphur ore: worked for the lead.
Wicklow.	8	Bray Head.	Bray—*Cambrian.*
,,	12 &c.	*Douce Mountain.* *Powerscourt.*	Enniskerry — Near the junction of *Granyte* and *Mica schist* (*Ordovician*). —Lead also.
,,	7 &c.		
,,	12	*Lough Tay.*	Togher, or Roundwood—Junction of *Granyte* and *Mica schist.*—With lead and zinc.
,,	17	*Lough Dan.*	
,,	25	*Ashford.*	Ballinalea—*Ordovician.*
,,	25	*Ballymacahara.*	
,,	22 & 23	*Glenmalure Mines.*	Rathdrum—Junction of *Granyte* and *Mica schist*—In the lead mines a little copper occurred at Ballinagoneen, Camenabologue, and Ballinacarrig, Lower.—*See Lead List.*
,,	28	Aghavannagh.	Aughrim—*Metamorphic Ordovician* (?) Ancient mine at Moneyteigue.
,,	34	Aughrim, Lower.	
,,	39	*Moneyteigue.*	
,,	38	Tinnahely.	North of . . —*Ordovician.*—Iron ochre and malachite.
,,	39	*Ballinagore.*	Woodenbridge, Carysfort Mines—*Metamorphic Ordovician.*—With iron and sulphur ore.
,,	39	*Ballinvalley.*	
,,	39	*Ballycoog.*	
,,	39	*Ballinasilloge.*	
,,	40	*Knocknamohill.*	Southwest Ovoca, or Knocknamohill, Mines—*Metamorphic Ordovician.*—Old mines worked for iron; the copper and sulphur ore worked a little. The prospects at Killeagh are bad; also those in the north portion of Ballymoneen.
,,	35 & 40	*Ballinapark.*	
,,	35	*Killeagh.*	
,,	35	*Ballymoneen.*	

COUNTIES.	No. of Ordnan'e Sheet.	LOCALITIES.	REMARKS.
Wicklow.	35	*Ballymurtagh.*	WEST OVOCA, OR BALLYMURTAGH, MINES —*Metamorphic Ordovician.*—The old mines were worked for copper, sulphur ore and iron. The prospects at Kilcashel and Knockanode not good. At Tinnahinch and Kilqueeny no trials have as yet been made.
,,	35	*Ballygahan, Upper.*	
,,	35	,, *Lower.*	
,,	35	Tinnahinch.	
,,	35	Kilqueeny.	
,,	35	*Kilcashel.*	
,,	35	*Knockanode.*	
,,	35	*Tigroney.*	EAST OVOCA, OR CRONEBANE, MINES—*Metamorphic Ordovician.* — Worked principally for sulphur ore, copper, iron, and ochre; at East Cronebane (Magpie), Connary, and Kilmacoo also for lead. At the latter mines there is the peculiar mineral, Kilmacooite.—*See Lead list.*
,,	35	*Cronebane.*	
,,	35	*Castlehoward.*	
,,	35	*Avondale* (Meetings).	
,,	35	*Shroughmore.*	
,,	35	*Connary, Upper.*	
,,	35	*Kilmacoo.*	
,,	35	*Kilmacrea.*	Redcross—*Metamorphic Ordovician.*—Associated with sulphur and iron ores. Some good looking "tumblers" of copper picked up at Ballykean.
,,	36	Templelyon.	
,,	35	Ballykean.	
,,	30 & 31	*Ballycapple.*	Wicklow, BALLYCAPPLE MINES—*Metamorphic Ordovician.*—Worked about 150 years ago for iron ore, which is a back to copper and sulphur ore.
,,	31	*Ballard.*	

SULPHUR AND GOSSANS.

[Sulphur occurs native, as concretions in the Carboniferous Limestone, in the counties of Galway, Mayo, and Wexford; but the principal Irish ore from which it is obtained is the sulphide of iron (*pyrite*): but in the Co. Galway pyrrhotite, or magnetic pyrites, is found, and has also been mined. These ores usually contain some units of copper (*chalcopyrite*): the more of the latter present, the greater the value of the ore; as after the sulphur is obtained copper can be abstracted from the ash. Some of the pyrrhotites are nickeliferous. Some conspicuous gossans and strong chalybeate springs will be included in this list; in some cases they may only indicate the presence of iron, yet in many cases they come from pyrite veins. The localities where the quantity of pyrite is small and valueless are not given.]

COUNTIES.	No. of Ordnan'c Sheet.	LOCALITIES.	REMARKS.
Cavan.	4 & 6	Legnagrove.	District of Glen, Native sulphur (?) (*Given in Lewis, but not of late years verified.*)
,,	5	Dowra.	
Clare.	26	*Ballyvergin.*	Tulla—*Carboniferous.*—Sulphur, lead, and copper.
,,	36 & 44	*Shannaknock.*	Broadford—*Ordovician.*—Coppery sulphur.

Counties.	No. of Ordnance Sheet.	Localities.	Remarks.
Cork.	107 & 108	Demesne.	Dunmanway—*Devonian* (?)—Said to be mundic, or poor ore.
,,	67	Fever Hospital.	Youghal—*Devonian* (?)—Strong spa.
,,	146	Kilcrohane.	Crookhaven — *Devonian.* — Thick lode sulphur ore with copper.
Donegal.	20	*Carrowmore*, or *Glentogher.*	Carndonagh—*Ordovician*, or *Cambrian.* Sulphur, silver-lead, and zinc.
,,	15	*Marfagh.*	Dunfanaghy—*Cambrian*, or *Ordovician.* Sulphur, copper, lead, and iron. The lode was principally worked for the lead.
,,	66 & 67	Scraig's Mountain.	Fintown—*Ordovician*, or *Cambrian.*—Sulphur, lead, and zinc.
,,	27	Carlan.	Carrowkeel—*Ordovician.*—Very strong, large, reddish spas.
,,	35 & 36	Goldrum and Casheleenan.	Kilmacrenan—*Ordovician* (?)—N. 10 W. lode, 3 feet wide; in part flucan, and in part quartz, with coppery sulphur ore; underlying eastward at 75°. Also a N. 20 E. quartz lode, with coppery stains and strong coppery spa.
,,	36	Ballyscanlan (Fern Hill).	Millford—*Ordovician.*—A nearly N. and S. line of strong spas.
,,	62	Fycorranagh.	Letterkenny — *Cambrian* (?) — Strong, reddish spas in the glen at the north-western boundary of the townland.
			Note.—In the metamorphic rocks (*Ordovician*, or *Cambrian*) there are numerous spa springs; some are solely due to the leaching of the iron (*carbonate* ?) out of the rocks; but when in lines along a line of break, or dyke, they may possibly point to mineral lodes.
Down.	28	Spa Cottage.	Ballynahinch—*Ordovician.*—Iron spa.
,,	45	St. John's Point.	Killough — *Ordovician.*— Sulphur and copper.
,,	34	Lisnasliggaun.	Banbridge—*Ordovician.*—Iron spas.
,,	34	Tanvally.	
,,	28 & 35	Finnisbridge.	
Galway.	—	—	Note.—For sulphur ore in the Co. Galway Carboniferous limestone *see Lead and Copper lists.*

COUNTIES.	No. of Ordnan'e Sheet.	LOCALITIES.	REMARKS.
Galway.	54	Eighterard.	Oughterard—*Carboniferous Limestone.* —Concretions of native sulphur.
,,	54	Carrowmanagh.	
,,	54	Fough.	
,,	40	*Ballygally.*	Oughterard—*Metamorphic Cambrian,* or *Ordovician.* — At Derreennagusfore the ore is magnetic pyrites (*pyrrhotite*). In some of the copper mines in this district there are considerable quantities of sulphur ore.—*See Lead and Copper lists,* and *Geological Survey Mem. Ex. Sheets* 93, 94, 95, and 105. The mine at Ballygally was one of the first opened; it was worked by Nimmo.
,,	40	*Gowlaun.*	
,,	40	*Gortnashingaun.*	
,,	40	Farravaun.	
,,	40	*Drumminnakill.*	
,,	40	*Newvillage.*	
,,	54	Derryeighter.	
,,	53	Leam East.	
,,	53	Letterfore.	
,,	39	*Currane.*	
,,	39	*Derreennagusfore.*	
,,	39	*Derry.*	
,,	94	Galway Dock.	Galway—*Ordovician.*
,,	90	*Maumeen.*	Gorumna Island — *Granyte.*—Coppery sulphur ore.
,,	90	*Teeranea.*	
Galway.	27	Ashford.	Cong—*Carboniferous.*
,,	40	Doorus.	,, *Ordovician.*
,,	39	*Doughta.*	Maum Bridge — *Metamorphic Cambrians* (?)—At Maumean, Lackavrea, and Maumwee the ore is coppery pyrrhotite, in part slightly nickle-iferous.
,,	39	*Maumwee.*	
,,	39	*Lackavrea.*	
,,	38	*Maumean.*	
,,	38	*Teernakill, South.*	
,,	25	Cur.	
,,	25	Teernakill, North.	
,,	10 & 23	Dawrosmore.	Clifden—*Metamorphic Cambrian* (?)
,,	9 & 10	Cloonlooaun.	
,,	9	Cashleen.	
,,	21	High Island.	
,,	22	Boolard.	
,,	35	Drimmeen.	
,,	24	Kylemore.	Recess—*Metamorphic Cambrian.*—The Ore is pyrrhotite. A little west of Recess are gossany "shode stones."
,,	24	Gleninagh.	
Limerick.	—	—	NOTE.—For sulphur ores *see lists of the Co. Limerick Lead and Copper mines.*
Mayo.	86	Louisburgh.	Vicinity of . . —*Silurian.*—Coppery sulphur.

COUNTIES.	No. of Ordnan'e Sheet.	LOCALITIES.	REMARKS.
Mayo.	65	Achill Island.	Molrenny (Clew Bay)—*Metamorphic Ordovician* (?)—Coppery sulphur.
,,	85 &c.	Clare Island.	
,,	65 & 75	*Curraun Achill* (Gubnabinnia Bay).	
,,	114	*Bofin Island.*	Cleggan — *Metamorphic Ordovician.*—Coppery.
,,	121	Ballycurrin.	Headford — *Carboniferous.* — Sulphur and lead.
,,	121	Gortbrack.	
			NOTE.—For sulphur ore in the Mayo Lead and Copper Mines, *see Lead and Copper lists.*
Tipperary.	—	—	At Lackamore mine, near Newport, and in different places in Silvermines, there is sulphur ore associated with the lead, &c. In the latter (Cloonanagh) there is a great "ramp" of poor ore (*mundic*).—*See lists Lead and Copper.*
Tyrone.	45	Aghafad.	Pomeroy—*Silurian.*—Coppery gossans; none of the lodes proved.—*See Copper list.* In the country hereabouts, and to the westward in the large tract of Silurian rocks of the *Lower Devonian* type, are many good-looking indications of minerals.
,,	45	Shanmaghry.	
,,	45	Lurganeden.	
,,	45	Glenbeg.	
Wexford.	25	Bree.	Enniscorthy—*Ordovician.*—Mundie.
			NOTE.—The iron ore at Ballybrennan (*see Iron list*) may possibly be the back of a sulphur ore lode.
Wicklow.	30 & 31	BALLYCAPPEL MINES.	The principal minerals in these mining setts, all of which lie in the *mineral channel* of the Ovoca valley, are coppery sulphur ores. Some of the best of these, however (in old times), were worked solely for the copper in them.—*See Copper list.*
,,	35	KILMACREA ,,	
,,	35	EAST OVOCA ,,	
,,	35	WEST OVOCA ,,	
,,	39 & 40	SOUTH-WEST OVOCA MINES.	
,,	39	CARYSFORT MINES.	

BARYTES.

[Only the localities where the ore is known to be in quantity are given.]

COUNTIES.	No. of Ordnan'e Sheet.	LOCALITIES.	REMARKS.
Cork.	118	*Derreengreanagh.*	Bantry—*Yellow Sandstone*, or *Devonian.*—With a little copper.
,,	118 & 119	*Derryginagh.*	
,,	140	*Ballycummisk.*	Ballydehob—*Yellow Sandstone*, or *Devonian.*—The ore in one lode is so mixed with copper ore that both are valueless.
	139	*Mount Gabriel.*	Skull—*Yellow Sandstone*, or *Devonian.*—A little copper.
,,	143	Little Island.	Roscarberry—*Yellow Sandstone*, or *Devonian.*—Some copper.
Down.	39	Gun's Island.	Ardglass—*Ordovician.*—With lead and copper.
,,	51 & 54	Dromore.	Vicinity of . . —*Ordovician.*—With lead.
,,	45	Rathmullen.	Killough—*Ordovician.*—With lead.
Galway.	54	Clooshgereen.	Oughterard—*Metamorphic Ordovician*, or *Cambrian.*—With copper and sulphur ore. Griggins is in the Maum Valley.
,,	54	Canrawer.	
,,	54	Cregg.	
,,	25	Griggins.	
,,	42	Bunnaconeen.	Headford—*Carboniferous.*
Limerick.	25	Oolahill.	Oola—*Carboniferous.*—With lead and copper.
Londonderry.	40	Cavanreagh.	Draperstown—*Carboniferous.*—Veins in sandstone.
Monaghan.	25	Carrickaganran.	Castleblaney—*Ordovician.*—With silver-lead.
,,	25	Cornalough.	
,,	14	*Coolartragh.*	Monaghan—*Ordovician.*—With silver-lead and zinc.
Sligo.	6 & 9	*Glencarberry* (King's Mountain).	Sligo—*Carboniferous.*—With some copper and lead.
Wexford.	43	Killane.	Wexford—*Carboniferous.*—With lead.
,,	43	South Intake.	
Wicklow.	23	*Baravore.*	GLENMALURE MINES, Rathdrum—*Granyte* and *Mica schist.*—With lead and zinc: very pure.

IRON.

[The Irish iron ores occur in bedded masses and in veins. In the recent accumulations, principally the alluvium and bog, iron occurs very frequently, often associated with manganese (*Wad*) as *bog-iron-ore*. In the Cainozoic rocks of Antrim and Derry are allied ores known in the trade as the "Belfast Aluminous Ore," which occur as bedded masses in the Eocene (?) Dolerytes. In the rocks of the Carboniferous period are clayey chalybites, as nodules and layers in the Calp and Coal Measures, while in the purer limestones of the same period, and the older Devonian, Ordovician, and Cambrian rocks, are regular veins and bunches of hematite, limonite, and chalybite. Some of the iron ores, however, in these older rocks, seem in part to be bedded or to partake of the nature of the veins known as *lay in lay*, that is, they underlie in the bedding of the associated rocks. Some, however, seem, and may be, more intimately connected with the associated strata, as a portion of a bed or beds may have been ferriferous, thus forming a bedded "bunch of ore."

The localities where "bog-iron-ore" occur are so numerous, that it would be impossible to enumerate them, but when particularly conspicuous they will be referred to. During the smelting operation in the 16th and 17th centuries, when the Irish iron industry appears to have been at its height, these bog ores seem to have been extensively worked to mix with the other ores. At the present time a peaty variety is at times extensively exported to England and Scotland, principally from Donegal, to be used for the purification of gas and other purposes. In general, it is found as layers in the peat, and may be from blackish to a dirty white in colour, but more often it is of a pale yellowish green; these, when exposed to the air, rapidly oxidize, changing in colour to yellow or reddish yellow. The bog-iron-ore is employed by gas manufacturers to purify the gas from sulphuretted hydrogen. In the process the ore becomes charged with sulphur, thereby becoming very valuable for the production of pure sulphuric acid. The residue (*brown ochre*), is also valuable, being sold for the manufacture of paint.

It appears remarkable, that the older deposits, especially in the alluvium, are of much greater magnitude than any that are now accumulating. This possibly may be due to the older masses being, in a great measure, the leaching from the surface rocks; which leaching process, being now long since accomplished, the present depositions have to depend solely on the iron brought up in springs from more or less deep-seated rocks].

BEDDED IRON ORES.

[These are arranged in groups, beginning with the younger formation, which necessitates the counties not being arranged in alphabetical order.]

EOCENE (?)

COUNTIES.	No. of Ordnan'e Sheet.	LOCALITIES.	REMARKS
Antrim.	—	Knockbay.	*Antrim Iron Measures—Limonite.*—In lenticular bedded masses in the dolerytе; apparently on different geological horizons: the better and richer beds being higher than the others. Associated with *lithomarge* (ferriferous clay), *bole* (a poor clayey iron ore), *alumyte* (alum clay), and *lignyte*—(*see Alum and Copperas list*). The best developed beds occur principally in the eastern and northern portions of the county. The iron ores proper consist of the First, or *pisolitic ore*, and the Second, or *aluminos ore;* but in some cases in the underlying lithomarge are lenticular masses of bole of a quality equal to the "Second ore." At Killymurrish, according to the records of a bore-hole, the Iron Ore Measure rested on White Limestone, as at Craig-na-Shoke, Co. Londonderry.
,,	—	Ballylig.	
,,	—	Broughshane.	
,,	—	Glenravel.	
,,	—	Cargan.	
,,	—	Newtown Cremmelin.	
,,	—	Glenariff.	
,,	—	Carnlough.	
,,	—	Glenarm.	
,,	—	Killymurrish.	
,,	—	Shanehill.	
,,	—	Larne, west of.	
,,	—	Island Magee.	
,,	—	Ballypalady.	
,,	—	Port Moon.	
,,	—	Rathlin Island.	
,,	—	Kellygar.	
,,	—	Swanstown.	
,,	—	Tully.	
,,	—	Kinboe.	
,,	—	Cullaleen.	
,,	—	Pharis.	
Londonderry.	35	Craig-na-shoke.	*Limonite.*—Two miles N. N. E. of Moneyeany there is a bed at the base of the Eocene dolerytes, associated with lignyte and the basal Chalk (*White Limestone*) conglomerate. There is a tradition that Rennie, about 1600, worked a similar ore on Slieve-Gallion-Carn, but none of the ore can now be seen.
,,	35	Moydamlaght.	
,,	35	Bohilbreaga (Dunmurray).	
,,	41	*Slieve-Gallion-Carn.*	

COAL MEASURES (Carboniferous).

COUNTIES.	No. of Ordnan'c Sheet.	LOCALITIES.	REMARKS.
Carlow.	—	LEINSTER AND EAST MUNSTER COAL-FIELDS.	Layers of nodules and thin seam of *clay-iron stone* on different horizons. The most productive beds occur a little below the lowest coal (*Gale Hill*, or *Cullenagh, coal*), and were extensively worked in the Queen's County in the 16th and 17th centuries. These ores were used at the furnace near Mountrath (Coote's) to mix with Bog and Carboniferous ores.—(*See County History.*)
Kilkenny.	—		
Queen's Co.	—		
Tipperary.	—		

Counties.	No. of Ordnan'e Sheet.	Localities.	Remarks.
Cork. Kerry. Limerick. Clare.	— — — —	West Munster Coal-fields.	Layers and nodules of *clay-iron stone:* principally associated with the lower coals—they were worked very extensively in the 16th and 17th centuries in the counties Limerick and Clare adjoining the Shannon. Iron ore was smelted at Glin, Loghill, &c.; but a portion of the ore seems to have been sent up the Shannon, to the furnaces on Lough Derg, to be mixed with Bog and Ordovician ores.—(*See County History.*)
Mayo.	—	Slievecarna.	The hills northward of Balla.—Clay-iron stone associated with the lowest coal.—(*See County History.*)
Sligo. Roscommon. Leitrim. Fermanagh.	—	Connaught Coal-field.	This field, although in general called after the province of Connaught, lies nearly equally in the province of Ulster. The iron-producing measures are in the Middle Coal Measures, and considerably below the geological horizon, in which the more profitable beds are found in Leinster and Munster. The iron (*clay-iron stone*) was extensively smelted formerly, and apparently at a later date than in the southern province—the fires having been put out when the wood-fuel was exhausted. In the Co. Fermanagh, at the foot of the Cuilcagh mountains, there were extensive excavations, furnaces, and mills; also in the Co. Leitrim—the last fire, at Drumshambo, having been put out in A.D. 1765. In the Co. Roscommon the three brothers O'Reilly first attempted in Ireland to smelt iron with coal: they, in 1788, establishing the Arigna Iron Works, and opened coal pits—the adventure, by them and others, being carried on till 1808. Since then others have tried. Full particulars of the more recent works are given hereafter in the *County History.*
Tyrone. ,, ,, ,,	46 47 46 & 47 39	*Drumglass* (Dungannon). *Annagher.* *Coalisland.* *Annaghone* (Tullahogue).	Tyrone Coal-field.—These are more or less detached. In none of them has much *clay-iron stone* been recorded. This possibly may be due to the measures—which in Connaught and elsewhere have produced most ore—being in this country more or less covered up by deep drift, and consequently not explored.

CALP (Carboniferous).

Counties.	No. of Ordnan'e Sheet.	Localities.	Remarks.
Antrim.	—	BALLYCASTLE COAL-FIELD.	*Clay-iron Stone.*—Worked in ancient times with the coal; also in the beginning of the eighteenth century, the ore having been smelted at Ballycastle by Mr. Boyd.—(*See County History.*)
Dublin.	5 & 8	Baldongan Hill.	Skerries—Poor *Clay-iron stone.*
,,	8	Donabate.	
Londonderry.	41	*Drumard.*	Draperstown — *Clay-iron Stone.* — Worked principally in Drumard, by Rennie, about 1600, and "smelted at the Drumlamph Iron Works." At the Moyola River, in the south part of Drumconready, there are the ruins of an old furnace.
,,	41	*Mormeal.*	
,,	41	*Brackaghlislea.*	
Mayo.	29 & 38	Crossmolina.	Barony of Erris—*Carboniferous* (?)—The exact position where the iron was raised for the use of Sir George Shaen's furnace near the Mullet, and Mr. Rutledge's, on the River Deel, is now uncertain; but it would appear as if the ore was procured, in part at least, from the Calpy limestone (*clay-iron stone*). Rutledge was the last to work, his fires being put out for want of fuel.—(*See County History.*)
,,	9 & 10	Tallagh.	
Tyrone.	29 & 38	Kildress.	Cookstown—*Limonite* and *Hematite.*—Extensive trials made about 1880 by the Barrow Hematite Company; but the works were stopped on account of the low prices for iron.
,,	—	DRUMQUIN CALP AREA.	Omagh—Nodular beds of *Clay-iron stone.*—Here, as near Draperstown and Cookstown, there are rocks belonging to the Ulster "calp type," in which the clay-iron stone is of a fair character.
Wexford.	49	Woarway Bay.	Hook Promontory, Fethard—Poor *Clay-iron stone.*—The ore is of a quality like that near Donabate, Co. Dublin. The associated rocks are also somewhat similar, but they rest on Carboniferous conglomerate (Upper Old Red Sandstone); in this locality they are probably a littoral accumulation.

IRON ORE IN VEINS.

[The mode of occurrence of some of the ores in this list is not as true veins; yet at the same time they are not in true beds. Like the ores of the Eocene and Coal Measures, they are apparently of a secondary formation, a part of a bed or beds becoming ferriferous, the ore being found in an irregular "bunch" or "shoot" that underlies with the stratification of the associated rocks. This is especially the case with some of the ores in the Ordovician rocks which have been described as "beds of ore." The localities of some of the ancient iron mines are now quite unknown, while the exact sites of others are uncertain. In the latter cases the places in the neighbourhood of which the mines were probably situated will be mentioned. The localities are arranged in counties.]

Counties.	No. of Ordnan'e Sheet.	Localities.	Remarks.
Cavan.	16	*Claragh.*	Redhill—*Ordovician.*—Ochre and limonite (?) The veins lie with the bedding of the rocks: ores worked in 1875.
Clare.	19 & 27	*Glendree.*	Feakle — *Ordovician* Limonite (?) — Worked prior to 1700. The adit of the ancient mine is still to be seen; but the exact position or nature of the lode is unknown. Tradition says that the ore was smelted at the present village of Furnace, a few miles eastward of Feakle. One mile N.E. of Feakle church are old *burrows*, where there is said to have been an "iron mine." The exact position of the lode is uncertain, without explorations.
,,	43 & 44	*Ballykelly.*	Broadford—*Ordovician.*
,,	—	*Knocksnaghta.*	Sixmilebridge — *Ordovician.*—Hematite and Limonite, with Graphite.
,,	28, &c.	*Ballymalone.* *Bealkelly.*	Tomgraney — *Ordovician.* — Limonite. Worked rather extensively in the 16th(?) and 17th centuries, principally for the furnaces along the shore of Lough Derg between Mt. Shannon and Woodford, where it was mixed with bog-iron-ore raised in that country, and "ore brought up the Shannon," probably from the Coal Measures, counties Limerick, Kerry, and Clare.
Cork.	128	Bear Island.	Bearhaven, or Castletown—*Carboniferous Slate.*—A well-marked vein of hematite, associated with micaceous iron ore.

COUNTIES.	No. of Ordnance Sheet.	LOCALITIES.	REMARKS.
Cork.	142	*Aghatubrid.*	Rosscarbery—*Yellow Sandstone*, or *Devonian.*—Limonite associated with manganese, the latter being in shrinkage fissures in the iron ore. The iron ore seems to occur as the back of a copper lode.
,,	143	*Roury Glen.*	
,,	143	*Rosscarbery.*	
,,	118 (?)	*Coomhola.*	Glengariff—*Carboniferous Slate* (?) or *Yellow Sandstone* (?)—A mine is recorded in this locality by Smith, in his history of Cork, 1750. Worked by the Whites, who had a furnace in the vicinity.
Cork.	—	*Aghadown.*	Roaring-water Bay and Tallow Bridge.—These localities are also mentioned by Smith, the first being worked by the Whites, the second by the Earls of Cork. According to Smith, 1750, iron was smelted by the Whites at Coomhola and Aghadown, and by Lord Cork at Araglin, "near the eastern extremity of the county;" while Gerrard Boate (1652) states the iron was smelted at Tallow Bridge. A few miles eastward of the latter, at Salter's Bridge, in the Co. Waterford, are the remains of old iron works, said to have been worked in the 17th century.—*See Drumslig, Co. Waterford.* The sites of the mines near Roaring-water Bay and Araglin are now unknown, but they were probably in the *Yellow Sandstone*, or *Devonian*, rocks of the vicinities.
,,	—	*Araglin.*	
,,	117	*Rooska.*	Bantry—*Carboniferous Slate.*—Chalybeate (*carbonate of iron*), with lead and copper: worked for the lead.
Donegal.	68	*Welshtown.*	Ballybofey—*Ordovician.*—With lead: the mine worked for the latter.
,,	15	*Marfagh.*	Dunfanaghy—*Ordovician* (?) or *Cambrian* (?)—With lead, copper, and sulphur ore: the mine worked, principally for the lead.
,,	36	Skreen, Lower.	Milford—*Ordovician* (?)—Limonite. In a mass of schist caught up in an intrude of whinstone. In the vicinity is a quantity of slag, as if smelting had formerly taken place.

Counties.	No. of Ordnan'e Sheet.	Localities.	Remarks.
Donegal.	53	Meenreagh.	Letterkenny — *Cambrian* (?) — Impure *chalybeate ;* appears to be more or less in bedded masses in the associated rocks. Note.—As has been pointed out by different recorders, the remains of ancient bloomeries and forges, used in the smelting of iron prior to the woods of the country having been used up, are found in different places scattered over the County.
Down.	35	*Deehommed.*	Banbridge — *Ordovician.*—Hematite. This vein has only been discovered about ten years. The ore appears to be of a good quality; but on account of the depression in trade it has not been worked.
,,	28	Spa Cottage.	Ballynahinch—*Ordovician.*
,,	28 &c.	Slieve Croob.	Dromara—*Ordovician.* (?)—In this tract of mountains, Griffith records iron in the townlands of Begny, Gransha, Leganany, Moneybane, &c.
,,	14	Carnreagh.	Hillsborough—*Ordovician.*
Dublin.	9	Lambay Island.	Skerries—*Intrusive Rocks.*—Blocks of hematite recorded by Du Noyer, as occurring a little S.W. of Raven's Well, near Bishop's Bay. Supposed to be from the back of a copper lode.
Fermanagh.	9	Rossbeg (Castle Caldwell).	Belleek — *Carboniferous* (?) — Limonite. Supposed to be the back of a copper lode. At Magheramereagh a little copper was raised by the late Mr. Johnstone.
Galway.	39	*Drumsnauv* (Doon).	Maum Bridge—*Metamorphic Ordovician.*—Hematite (?); with manganese, copper, and lead : worked for the lead.
Galway.*	35	Derreen.	Clifden — *Ordovician.* — Limonite in limestone.

* In the west of this county iron ore veins are not recorded; but in olden times ore was smelted in places, such as Lough-na-Furnace, Screeb, and in other places on Galway Bay or its inlet. In these places, however, it may have been bog-iron ore that was used, mixed with imported ore—as the records inform us that iron ore was imported into places along the west coast to be smelted, on account of the abundance of timber; the old iron being made with wood charcoal. In the south-east of the county there were extensive furnaces and mills adjoining Lough Derg, the last in work, that of Woodford, having its fires put out about the year 1750. The iron ores for these furnaces and mills were procured in the vicinity (*bog-iron ore*) near Tomgraney, Co. Clare (*limonite*), and from the Lower Shannon,

COUNTIES.	No. of Ordnan'e Sheet.	LOCALITIES.	REMARKS.
Kerry.*	—	—	—
Kilkenny.	28	Grenan.	Thomastown—*Ordovician.*—Red hematite (*micaceous*).
Leitrim.	35	*Gortinee.*	Drumsna—*Ordovician.*—Limonite raised here; probably in the 16th or 17th century. When making the railway from Longford to Sligo three bed-like veins of slaty limonite, bearing nearly N.E. and S.W., heading S.E. at 60° were cut. Subsequently they were worked, two shafts being sunk for a depth of thirty feet about the year 1870, by which the ore was proved to improve in depth. On the depression in the iron trade the works ceased (*See County History*).
Limerick.	11	Askeaton.	Askeaton—*Carboniferous Limestone, Silicious Limonite.*—The ore at Kilcolman was worked about the 17th century, and subsequently about the years 1870–75.
,,	—	*Kilcolman.*	
Londonderry.	31	Carrick Mountain.	Dungiven—*Ordovician* (?)
,,	29	*Glenrandal.*	Stranagallwilly—*Ordovician.*—Mass of Ochre.
,,	40 & 45	*Tullybrick* (Altihaskey).	Draperstown—*Ordovician* (?)—Red Hematite. One of Rennie's mines (A.D. 1600) is said to have been in this townland, but the site is now unknown.
,,	45	Beaghbeg.	Tonaragh—*Ordovician* (?)—Red Hematite (*micaceous*).

counties Limerick and Clare (*clay-iron stone*). Hely Dulton, in his Statistics, History Co. Galway, 1824, states:—"Iron ore was formerly raised in the neighbourhood of Woodford, and after being mixed with that brought up the Shannon from Killaloe by a Mr. Crossdale, was smelted near that village, part of the estate of Sir John Burke. The works were carried on so extensively, that they devoured all the great oak woods with which that country abounded, and were then abandoned. Mr. Berry, I understand, at present raises ore on part of Lord Clanricarde's estate."

* At the present time there are no records of mines solely worked for iron, but along the coast-line are the remains of different furnaces. According to tradition these belonged to Petty (ancestor of the Lords Lansdowne), who imported iron ore about the year 1600, to smelt it with charcoal, made in the wood which then abounded in the country. Nennius, writing in the ninth century (*Historia Britonum*) mentions iron as being worked in the neighbourhood of Killarney Lakes; but the site of the old mine is now unknown. The remains of very ancient bloomeries and furnaces have been found at Killarney and Blackstones (*See County History*).

Counties.	No. of Ordnan'e Sheet.	Localities.	Remarks.
Londonderry.	40 & 45	(*Unagh*) Slieve Gallion Carn.	Moneymore—*Granyte.*—Hematite in a four-foot vein of ferriferous quartz: worked by Rennie in 1600, and recently, about 1875.
,,	46	*Tirgan* and *Carndaisy.*	Moneymore—*Granyte.*—Four-foot lode, being N.S.S.W., and hading S.W. at 8°; rich fibrous hematite (*kidney ore*), and *red ochre:* worked by Rennie, and recently.
,,	45 & 46	*Slievemoyle.*	Moneymore—*Metamorphic Ordovician.* —Hematite and barytes: worked a little in 1875. A narrow, nearly vertical vein, with a north-westerly course.
,,	46	*Cranny* (Glenview).	Desertmartin—*Metamorphic Ordovician.* —Hematite and barytes. A narrow, nearly vertical, lode, with a north-westerly course: worked a little in 1875.
Longford. ,,	3 3	*Cleenragh.* *Enaghan.*	Arvagh — *Ordovician.*—These bed-like veins of limonite are similar to those at Gortinee, Co. Leitrim; but the ore at Cleenragh is of a better quality, while that at Enaghan is not as good. Worked in the 16th or 17th century, and rather extensively, by Dr. Ritchie of Belfast, between 1860–70.
Louth.	22	Clogher Head.	Clogher—*Ordovician.*—Limonite.
Mayo. ,,	— 75	Carricknahelty. Curraun Hill.	Molrany—*Ordovician.*—Limonite.
Meath.	2 & 3	Corratober.	About two miles to the south-east of Kingscourt are numerous tumblers and fragments of hematite. Source not known; possibly near at hand.
Queen's Co. ,,	13 & 18 13	*Dysart.* *Dunamase.*	Maryborough—*Carboniferous Limestone.* —Limonite: worked extensively in the 16th and 17th centuries, the ore having been brought to be smelted to Coote's furnace, at Mountrath.
Sligo.	27	Ballynakill.	Riverstown—*Carboniferous.*—Hematite veins in the bedding lines. An ancient furnace close to the mineral veins.

COUNTIES.	No. of Ordnan'e Sheet.	LOCALITIES.	REMARKS.
Sligo.	21	Ballintogher.	Ballysadare.—There are old iron mines recorded at Ballintogher. At the base of the Ox Mountains were very extensive workings; while furnaces and mills were situated at Screevenamuck; the fire having been put out in 1768 for the want of wood-fuel (*See County History*).
Tipperary.	45	Scotchman's Coom.	Cappaghwhite—*Ordovician.*
,,	33	Gortnahulla.	In the valley of the Clodiagh, Borrisoleigh — *Ordovician.* — Limonite. A very old mine; when and by whom worked is not known. The iron ore seems to be the back of a copper or sulphur ore lode. Tradition says there was a second mine to the N.E., near Roscrea, but the site seems to be now unknown.
Tyrone.	29	*Lissan.*	Cookstown—*Carboniferous.*—Hematite, limonite, and ochre, with manganese. Worked in 1600 by Rennie, and subsequently between 1865 and '75.
,,	37	*Bardahessiagh.*	Pomeroy—*Metamorphic Cambrian* (?)—This occurs in a mass, and appears to be an intrude of whinstone highly impregnated with *magnetite.* It has been worked as an iron ore, but not successfully.
,,	37	Limehill.	Pomeroy—*Granyte.*—An impure chalybeate in an irregular vein.
Waterford.	7	Killerquile.	Carrick-on-Suir — *Ordovician.*—Hematite (*micaceous-iron-ore*).
,, ,,	35 35	*Dromslig.* *Grallagh.*	Dungarvan—*Devonian,* or *Yellow Sandstone.* — Hematite discovered and worked by Walter Raleigh about, or a little before, 1600. Subsequently worked between 1850 and 1860.
,, ,,	39 40	*Mine Head.* *Ardmore.*	Ardmore—*Devonian,* or *Yellow Sandstone.*—Limonite. Probably worked in the 17th century

Counties.	No. of Ordnan'e Sheet.	Localities.	Remarks.
Wexford.	31	*Ballybrennan.*	Enniscorthy—*Ordovician.*—The workings here appear to have been ancient, as nearly all traces of them are obliterated.
,,	7	Ballynastragh.	Gorey—*Ordovician.*—These accumulations are in part of the nature of beds. At and in the neighbourhood of Ballynastragh portions of a bed or beds of purple slate are highly ferriferous (*limonite*). Near Courtown the same ore occurs as strings or veins in the rocks, while northward of Ballymoney Fishery there are lenticular beds of poor *chalybeate.*
,,	12	Courtown Harbour.	
,,	7	Ballymoney.	
Wicklow.	6	*Cloghleagh.*	Blessington (Glenasplinkeen) — *Metamorphic Ordovician.*—Limonite, hematite, and manganese; worked a little.
,,	5	Knockatillian.	
,,	42	*Aughowle Upper.*	Shillelagh—*Metamorphic Ordovician.*—Limonite. Some trial made on the vein about 1875. Iron ore is said to have been raised in this locality in Bacon's and Chamney's time (16th and 17th century); but the sites of their works are now unrecorded.
,,	38	Tinnahely.	North of . . —*Metamorphic Ordovician.*—A ramp of limonite partaking of the nature of bog-iron-ore; for the most part at the surface, or only under a thin drift: in places it is copper-stained. No traces of old or recent works in connexion with it are apparent.
,,	29 & 34	*Mucklagh.*	Rathdrum—A rather extensive ferriferous conglomerate on *Metamorphic Ordovician* (?). Unsuccessfully open casts were made in part of it (1875), to try and find its source.
,,	39	*Moneyteigue.*	Woodenbridge, Carysfort Mines—*Metamorphic Ordovician.*—Limonite: the backs of copper and sulphur-ore lodes. Very ancient working appears to have existed here; while in recent years some tons of ores have been raised at Moneyteigue.
,,	39	*Ballycoog.*	
,,	39	*Ballynasilloge.*	
,,	40	Mongaun.	Arklow — *Metamorphic Ordovician.* — A large ferriferous mass, somewhat like that at Mucklagh. No trials have been made to seek for its source.

COUNTIES.	No. of Ordnan'e Sheet.	LOCALITIES.	REMARKS.
,,	40	*Knocknamohill.*	SOUTH-WEST OVOCA, or KNOCKNAMOHILL MINES—*Metamorphic Ordovician.*—Limonite: the backs of copper or sulphur-ore lodes; worked in the 17th century, the ore being sent to Chamney's furnaces at Ballynaclash, Shillelagh, &c.
,,	35 & 40	*Ballinapark.*	
,,	35	*Ballymoneen.*	
,,	35	*Ballymurtagh.*	WEST OVOCA MINES — *Metamorphic Ordovician.*—Limonite with copper-staining on the shrinkage fissures, and ochre. The back of the North sulphur lode was not worked till recent years, and iron is at present being raised: of late the ochre has been worked.
,,	35	*Castle Howard.*	EAST OVOCA MINES—*Metamorphic Ordovician.*—Limonite and ochre. Worked in late years; ochre at present being raised and manufactured. The backs of copper and sulphur-ore lodes.
,,	35	*Cronebane.*	
,,	35	*Connary.*	
,,	35	*Kilmacoo.*	
,,	36	*Templelyon.*	Redcross — *Metamorphic Ordovician.*—Limonite.
,,	30 & 31	*Ballycapple.*	Wicklow—*Metamorphic Ordovician.*—Limonite, magnetite, chalybeate, and ochre, with manganese: seems to be the back of a copper or sulphur-ore lode. Here there were extensive works in the 17th century, the ore being smelted by Chamney in the Vale of Clara, at Ballynaclash furnace, &c.; the old mines are still called the "Clash pits."
,,	31	*Ballard.*	

MANGANESE.

[This mineral is very universally distributed, but generally more or less minutely; it is very often associated with bog-iron-ore, or other iron peroxides. In many cases it is valueless. In this list are only given the localities where it might possibly be worked profitably as a bye-product with the associated minerals.]

COUNTIES.	No. of Ordnan'e Sheet.	LOCALITIES.	REMARKS.
Armagh.	19	*Clay.*	Keady—*Ordovician.*—With lead; not in large quantity.
Clare.	6	*Cappagh.*	Ballyvaughan — *Carboniferous.*— Associated with lead.
,,	27	Glendree.	Feakle—*Drift.*—(*Diallogite*).

Counties.	No. of Ordnance Sheet.	Localities.	Remarks.
Cork.	143	*Aghatubrid.*	Rosscarbery — *Yellow Sandstone*, or *Devonian.* These mines are on one channel. In considerable quantity associated with iron and copper.
,,	143	*Roury Glen.*	
,,	143	*Rosscarbery.*	
Donegal.	89	Malinbeg.	Killybegs—*Metamorphic Ordovician* (?) —With silver-lead.
Galway.	39	*Drumsnauv* (Doon).	Maumbridge—*Ordovician.*—With copper, lead, and iron.
Monaghan.	27	Corduff.	Bellatrain—*Ordovician.*
Tipperary.	74	*Aherlow Vale.*	Tipperary—*Ordovician.*—With silver-lead and copper.
Wicklow.	6	*Cloghleagh.*	Blessington (Glenasplinkeen) — *Mica Schist.*—With iron.
,,	5	*Knockatillane.*	
,,	30	*Ballycapple.*	Wicklow—*Ordovician.*—With iron and copper.
,,	31	*Ballard.*	

ANTIMONY.

[It, in general, occurs as the sulphide (*stibnite*) associated with lead (*galenite*).]

Counties.	No. of Ordnance Sheet.	Localities	Remarks.
Clare.	34	*Monanoe*, or *Kilbreckan.*	Quin — *Carboniferous.* —With silver-lead.—*See Lead list.*
Cork.	142	Rabbit Island.	Castletownsend—*Yellow Sandstone*, or *Devonian.*—Associated with lead and copper.
Louth.	1	Jonesborough.	Vicinity of . . —*Ordovician.*
Monaghan.	14	*Lisglassan.*	Monaghan — *Ordovician.*— With lead. At Clontibret the vein of stibnite is four inches wide.
,,	14	*Tullybrack.*	
,,	14	*Clontibret.*	
Tyrone.	12 & 19	Munterlong Mountain.	Newtownstewart — *Ordovician.* — Recorded by *Griffith.*
Wicklow.	35	*Cronebane* (Magpie).	Ovoca —*Metamorphic Ordovician.*—In the Kilmacooite.—*See Lead list.*
,,	35	*Kilmacoo* (Connary).	

ARSENIC.

[This mineral is very often present in small quantities associated with sulphur-ore (*pyrites*), and sometimes with lead. At Cronebane and Connary, Co. Wicklow (sheet 35), it occurs as arsenopyrite, locally called "Jack Martin," with the sulphur-ore, and in the Kilmacooite (see Lead and Zinc); at Lackamore, Co. Tipperary (sheet 38), it occurs as arsennopyrite associated with copper ore; but in some places it occurs independently, as on the east shore of Adrigole Bay, Co. Cork (sheet 118), and at Gubnabinniaboy, near Molranny, Co. Mayo (sheets 65 and 75). In some of the mines of south-west Cork, as at Lissaremig, near Bantry (see Lead List), it occurs in considerable quantities.]

COBALT.

[Cobalt in quantity has only been recorded as occurring at Muckross, Co. Kerry, where, unfortunately, most of the ore (*erythrite*, or *arsenate of Cobalt*) was thrown into the lake before its value was discovered.—(*Kane.*)]

COUNTIES.	No. of Ordnan'e Sheet.	LOCALITIES.	REMARKS.
Donegal.	35	Barnesbeg.	N. of Kilmacrennan.—Traces in pyrrhotite crystal. (*Scott.*)
Dublin.	15	*Sutton.*	Howth—*Carboniferous.*—With manganese. Discovered by *Dr. Stokes.*
Kerry	74	*Muckross.*	Killarney — *Carboniferous.*—Associated with copper and pyrites. The major portion of the cobalt ore was thrown into the lake before its nature was discovered by *M. Raspe* in 1794.
Waterford.	25	*Knockmahon.*	Bunmahon — *Ordovician.* — Associated with copper, silver-lead, and zinc. Discovered by *J. H. Holdsworth.*

GRAPHITE (Plumbago).

[Graphite has been very little utilized, although in some places it seems to be in sufficient quantity to have been worked as a bye-product with the associated minerals.]

Counties.	No. of Ordnan'e Sheet.	Localities.	Remarks.
Clare.	43	Knocksnaghta.	Sixmilebridge—*Ordovician.*—In a vein with iron.
Donegal.	26	Sheephaven, near Ards House.	Dunfanaghy and Convoy.—Found as rolled pieces in *Gravel.*
,,	69	Burndale.	
Kilkenny.	—	Castlecomer Coal-field.	*Carboniferous.*—Fomerly associated with the "old Three-Foot Coal."
Mayo.	65	Toorrevagh.	Achill Island — *Ordovician.*—Graphitic micalyte to the east of Doonaglass Point. (*Mitchell.*)
Tipperary.	40	Gleninchinaveigh.	Upperchurch—*Ordovician.*—In a lode, associated, or mixed, with anthracite. The lode was worked to a depth of ten fathoms, when the walls closed in and cut it out.
Wexford.	7	Ballymoney.	Courtown —*Ordovician.*—Disseminated in beds of black shale.
,,	20	Greenfield.	Enniscorthy—*Ordovician.*
,,	25	Craan.	Wilton—*Ordovician.*—In a vein, associated with anthracite.
,,	31	Doonoony.	Taghmon — *Ordovician.* — In a vein, associated with anthracite.
Wicklow.	30	Rathdrum.	N.E. of Rathdrum, Ovoca—*Ordovician.*—In these places it occurs disseminated in black shaly clays locally called *Coal-ground.*
,,	35	Avondale.	
,,	35	Cronebane.	

NICKEL.

[This mineral as yet has not been found in sufficient quantities to be profitable. It has, however, been detected in the *pyrrhotites* of the Maam and Gleninagh Valleys, Co. Galway. Hardman has found it in serpentine or allied rocks; such as *ophiolyte*, Lissoughter; *talcyte* (?) Mullaghglass, Co. Galway; *ophyte*, Croagh Patrick; *steatyte*, Bofin, Co. Mayo; and *ophyte*, or *eklogyte*, Slishwood, Co. Sligo.

In America there is a magnesian rock which is worked profitably for the nickel it contains; therefore attention may be directed to a rock found S.W. of Leenaun, to the north of Glenisky Peak, Co. Galway, and to a similar one in Achill Island, Co. Mayo; as in appearance they are very like the American rock. As yet neither of these have been tested for nickel.

Magnetic pyrites (*pyrrhotite*) crystals that occur at Barnesbeg, Co. Donegal, were found by Scott to have traces of nickel and cobalt.]

TITANIUM.

[Titanium is rare in Ireland, or has not been recorded. Specimens of *rutilite*, or *rutile*, the native oxide, have been found at Cushanacurragh, near Burrishoole, to the north-east of Clew Bay, Co. Mayo. In the Co. Donegal, Sir C. Giesecke records it as found in quartz peebles, River Dale, and in mica slate, Arranmore, while Mr. J. V. Stewart, records it at Malinbeg and Ards. Recently bunches of small crystals have been found in Rosscuile, in the same county.]

MOLYBDENITE.

[This mineral appears to occur in rather considerable quantities disseminated in a wide endogenous granitic vein in the townland of Murvey, near Roundstone, Co. Galway (sheet 63). Elsewhere it does not appear to be recorded in quantity. Haughton found it in oligoclase veins at Garvany, near Castle Caldwell, Co. Fermanagh; while R. H. Scott found it in an elvan at Lough Laragh, near Glenties, and J. V. Stewart at Lough Anure, both in the Co. Donegal.]

ALUM AND COPPERAS.

[Alum shales frequently occur in the *Lower Coal Measures*, especially in the Province of Munster, while pyritous shales, suitable for the manufacture of copperas, are also found, especially in the *Upper Coal Measures*. To the pyritous shales special attention was directed by Kane, in 1844, but since then no one seems to have endeavoured to utilize them. Near Castleisland, Co. Kerry, are pyritous shales, called *Lapis Hibernicus Auctorum*; these at one time were used in the manufacture of copperas at Tralee.

Some few years ago Mr. Walter Jameson, of Glenarm, discovered an alum-clay (*alumyte*) in connexion with the lithomarge and iron ores of the Co. Antrim. This is at present worked in different places, but more especially near Ballintoy.

The alumyte must not be confounded with the French *Beauxyte*, or the German *Woheiryte*, both of which are ferriferous, and in aspect more or less similar to some of the varieties of the Antrim lithomarge and bole. The lithomarge and bole have not as yet been worked for alum; yet they seem to be allied to the alumyte, the latter appearing as if it was a secondary product; having been at first lithomarge, out of which the iron was leached by the associated lignyte, as the alumyte is always accompanied by the latter.—*See County History*.]

SALT AND GYPSUM.

[In Ireland salt and gypsum are only found in the Triassic rocks of two counties, and are more or less associated. In all the sinkings for salt, although not in the borings, gypsum has been found; but in different places the latter occurs without salt.]

Counties.	No. of Ordnan'e Sheet.	Localities.	Remarks.
Antrim.	20	Cushendall.	Near to . . —*Gypsum.*—Found in the "Keuper Marl."
,,	41	Ballylig.	Three miles south-east of Larne.—A bore-hole was put down in 1839, while making trials for coal, to a depth of 174 feet; at 150 feet *Salt Measure* was met, but the trial was abandoned before it was proved if a good bed of salt existed.
,,	53	Eden.	On Belfast Lough. A *Salt Spring* at the village.
,,	52	*Duncrue.*	Carrickfergus—*Salt* and *Gypsum.*—The Salt Measures, discovered in a trial in search of coal. In the old pit these are 162 feet in thickness, contain 110 feet of pure salt, and 13 of rock-salt; but in the new pit, 500 yards to the north, they are only about 100 feet thick; while to the S.W. of the old pit trials have been made without finding the Salt Measures. These data suggest that they are in a lenticular mass, or cake, of limited extent. The best salt-bed (88 feet thick) containing over 95 per cent. of pure salt.
,,	63 & 67	*Mullaghcarton*, or Multikartan.	Lisburn, Valley of the Lagan—*Gypsum.* —Recorded by Rutty in his *Natural History of Dublin*, 1772. Gypsum is known to exist in different places in the valley.
Tyrone.	30	Coagh.	S.S.W. of . . —In a pit sunk at the south side of the Ballinderry River thin seams, or beds, of fibrous *gypsum* occur in a red and green marl, 15 feet thick.
Monaghan.	31 & 34	Derrynasrobe.	Carrickmacross.—A cake of *gypsum.* In one place upwards of 60 feet thick. Was manufactured at Knocknacran into Plaster of Paris until the works were burnt down prior to 1870.
,,	31	Knocknacran.	
Meath.	2	*Raloaghan.*	S.E. of Kingscourt—*Gypsum.*—Proved by borings in the first townland; raised in the two others.
,,	4	*Newcastle.*	
,,	—	*Keernaghan.*	

APATITE.

[Apatite in quantity has not as yet been recorded in Ireland; but as some of the rocks are very similar to those associated with the apatite in Canada, especially some of the West Galway rocks, it may yet be found.]

COUNTIES.	No. of Ordnan'e Sheet.	LOCALITIES.	REMARKS.
Antrim.	—	—	In the Lias of the east coast some nodules (*coprolites*) have been found, but not in quantity.
Donegal.	27	Craanford.	Millford—*Ordovician.*—A poor apatitic limestone.
,,	37	Carn High.	Rathmelton — *Ordovician.*—A slightly apatitic limestone.
,,	35	Barnes, Upper and Lower.	Kilmacrenan—*Metamorphic Cambrian* (?) Scott records having found traces of apatite in these townlands.
Galway (?) Tyrone (?)	— —	West, or Yar-connaught. Slieve Gallion District.	*Ordovician* (?) or *Cambrian* (?)—Some of the rocks in both these areas are very similar to those, that in Canada, are associated with the apatite.

STEATITE AND PYROPHYLLITE.

[Steatite and pyrophyllite generally occur more or less deteriorated as the rocks,—*steatyte* (soapstone), and *pyrophyllyte* (camstone). They are very much confused in the records, both nearly invariably being called by the first name. *Steatyte* is for the most part made up of silicate of magnesia, and nearly invariably occurs as an adjunct of the intrusive rocks; although in some cases a "fault rock," made up of the *debris* of intrusive rocks may become a steatyte. They may pass into talcyte. The rock *pyrophyllyte*, is for the most part made up of silicate of alumina, and nearly always occurs in beds, as if it was a methylotic sedimentary tuffose rock. Nearly invariably it has a fibrous or elongated prismatic structure, and often passes into sericyte, or anhydrous micalyte.

The largest and most valuable recorded Irish localities for steatyte are in the Co. Mayo; while pyrophyllyte is more known in Donegal than any other country. Beds of steatitic clay, or "Fuller's earth" are found in different places, and formerly were much used for abstracting grease from woollen articles, while in the Co. Galway they are still used for that purpose. Pyrophyllyte has been used in the manufacture of lubricators, but as it contains about 30 units of alumina, it might possibly also be utilized in the manufacture of alum and alumina. Neither steatyte nor pyrophyllyte have been carefully looked for or recorded. The following list, therefore, may fall considerably short of the number of places in which they occur.]

Counties.	No. of Ordnan'c Sheet.	Localities.	Remarks.
Antrim.	47	Gobbin's Rock, Island Magee.	*Eocene* (?)—Steatyte.—Formerly extensively used for French chalk.
Cork.	128	S.W. of Dunboy.	Castletown, Bearhaven—*Carboniferous Slate.*—These, especially the first, appear to be dykes; the latter is cupriferous. Both seem to be more of the nature of pyrophyllyte than steatyte; but as yet have not been tested.
,,	127	Pulleen Harbour.	
Donegal.	37	Meenrea.	West of Rathmullen—*Ordovician* (?)—A bed of pyrophyllyte.
,,	17	Kildrummon.	South of . . —*Ordovician.*—The back of a bed of pyrophyllyte exposed at the shore.
,,	45	Cloony.	N.W. and N. of Rathmelton—*Ordovician*(?)—A bed or beds of pyrophyllyte: worked along the back, or outcrop, for clay to be used, as hearths.
,,	46	Carn.	
,,	44	*Clonkilty.*	Westward of Kilmacrenan — *Ordovician* (?)—In several places in the hills. In general the pyrophyllyte of the Co. Donegal is called *camstone* or *cambstone*. It has been quarried for architectural purposes.—See Wilkinson's *Practical Geology*.
,,	44	*Cottian.*	

COUNTIES.	No. of Ordnan'e Sheet.	LOCALITIES.	REMARKS.
Donegal.	44	*Carrowtrasna.*	West of Loughakib, Church Hill (Gartan)—*Cambrian.*—A bed of pyrophyllyte. Mined for some years profitably, and sold in the market under the trade-name of "steatyte."
,,	56	*Crohy Head.*	Dungloe—*Ordovician* (?)—Beds of pyrophyllyte (?): for some time mined to be used in the manufacture of lubricators.
,,	52	*Cabra Glebe.*	S.E. of Churchtown — *Ordovician.*— Pyrophyllyte bed: seems to have been worked in old times, but no opening has been made for many years. Adjoining the old working is a heap of peculiar saucer-shaped pieces of slag.
,,	79	*Gibbstown.*	W.N.W. of Castlefinn—*Ordovician.*— Pyrophyllyte, or "camstone," has been raised for years; in old times for architectural purposes, and more recently solely for slabs for furnaces. Camstone veins also occur in the country to the northward, between Castlefinn and Letterkenny, that appear to have been used for farm purposes.
Galway.	25	Kilmeelickin.	Maumbridge — *Ordovician.* — Tumblers and fragments of steatyte (?); the source not proved. In other places in this county small veins of steatyte are recorded as associated with the ophytes, but no considerable accumulation is recorded.
Mayo.	87, &c.	Croagh Patrick Range.	Westport—*Ordovician.*—Small accumulations and veins of steatyte, associated with the ophyte that forms the long tract (the largest in Ireland) extending from the N.W. slopes by Croagh Patrick to eastward of Westport. No large or pure vein, or pocket, is recorded.
,	65	*Claggan.*	Achill Island—*Ordovician.*—An irregular bunch, or "pocket-vein," of steatyte. A portion is crystalline and very pure: has been worked to a small extent.

Counties.	No. of Ordnance Sheet.	Localities.	Remarks.
Mayo.	107	Lugaloughaun.	Westport — *Ordovician.*— Pockets and veins of steatyte, associated with ophiolyte: first records by *Warren.* [*Geological Survey Mem. Ex. Sheets* 83 and 84, page 49.]
,,	106	Glencullian.	(Doolough) Louisburgh—*Ordovician.*— A dyke of mottled-green steatyte.
,,	106	*Cleggandadodda.*	Louisburgh — *Ordovician.*—A large yellowish mass, associated with an intrude of felstone; appears to be in part pyrophyllyte, and in part steatyte.
,,	114	*West Quarter.*	Bofin Island—*Ordovician.*—This island, as also Shark, lie off the coast of Galway, although in the Co. Mayo. A very important and large mass of steatyte, having in places very pure veins and pockets: has been worked a little.
,,	114	N.W. Coast.	Shark Island — *Ordovician.*—A large mass of steatyte; very similar to that on the opposite shore of Bofin.
Wicklow.	39	Killahurla.	Woodenbridge—*Ordovician.*—Dykes of an orange or yellow steatyte. In this county, also in Wexford and Waterford, associated with the basic eruptive rocks, are small veins of steatyte, but none of those recorded are of a size requiring a special notice.
,,	17	*Glenmacnass.*	S.E. portion—*Metamorphic Cambrian* (?) Pyrophyllyte (*camstone*); formerly (1837) worked for chimney-pieces, &c. The stone when first raised was quite soft, but after being cut rapidly hardened.

Note.—Steat*i*te and Pyrophyll*i*te in this list are minerals, while Steat*y*te and Pyrophyll*y*te are rock masses: that is, the minerals incorporated with impurities, as found forming beds or veins.

FLUOR OR FLUORSPAR.

Fluor or Fluorspar should be mentioned among Irish minerals, being an important flux in the reduction of iron. Unfortunately its value, until recent years, was not generally known, and the places in which it has been found are only sparingly recorded; while a search for it has not been made. Among the records, we find it mentioned as occurring in several of the lead mines in the Co. Clare; at Minna and Juverrin Mines, Co. Galway, of a violet colour; and in the same county, at Glengoola, of pale yellowish-green or bluish colour; while in the Mines of Glendalough, Co. Wicklow, it was found both crystalline and massive. None of the records, however, state that, as yet, it has been found in sufficient quantities to be of commercial value.

INDEX TO MINERALS.

Part II.—Brief County Histories.

These County Histories are placed in alphabetical order. In Part I., The Lists of the Mineral Localities—places where *salt*, *gypsum*, *steatite*, *pyrophylite*, and other useful products occur—are given, as the workings to obtain them are included under the general name of "Mines," although legitimately speaking they do not belong to "Metal Mining." On the same principle the localities for *coal* ought to have been mentioned, more especially as the coals are more or less connected with clay-iron-stone. Coal workings, however, are so important that universally they have been separated from Metal Mining, and have been given a distinct place of their own. Nevertheless, in these County Histories, it seems impossible to pass them over; they will, therefore, be briefly referred to, in the Counties in which they occur, in connexion with the iron-ores, the working of both being more or less connected. The Irish coals are of Eocene (?), Carboniferous, Ordovician, and perhaps of Cambrian ages.

Some of the statements made hereafter have not been verified, and in such cases the authorities will be mentioned. Much information can be learned from Lewis's *Topographical Dictionary*. The name of the writer of the geological descriptions is not given; but, as far as I have been able to test them, they appear trustworthy. Unverified statements, however, will be given on Lewis's authority.[1]

The English writers on Ireland, such as Spencer, Raleigh, Ledwich, Boate, and others, insinuate, or positively state, that the Irish, before the English came to the country, were perfectly incapable of finding or working minerals. This, however, the researches of the Antiquarian have proved to be perfectly incorrect, as the early Irish were eminent workers in gold, silver, brass, and, I believe, iron. Their trade degenerated, and perhaps altogether

[1] From the style adopted in these descriptions, I would suggest that Weaver was probably the writer.

ceased, during the internal wars before and after the advent of Strongbow and his mercenary companions. The statements of these writers as to early mining cannot, therefore, be relied on, although they may be quoted in reference to works that were in existence when they wrote.

In the early times gold and silver were recognized productions, especially gold, as pointed out in the Paper by the late Gerrard A. Kinahan, *On the mode of Occurrence and Winning of Gold in Ireland* (*Proc.*, R. D. S., vol. III., pt. v.). The English, prior to 1640, discovered and worked three silver-lead-ore veins in Antrim, Sligo, and Tipperary. The site of the mine in Antrim is now unknown, but probably it was somewhere in the Ballycastle Metamorphic rocks district. The Sligo mine was in Coney Island, but it also appears to be now unknown, or to be given a different name; while that in Tipperary was the Silvermines near Nenagh. The last, although claimed as an English discovery, had previously been worked by the Irish.

Boate (16) would have us believe that the English were the first to smelt and work iron. Chicester, however, in his report (1609), states he found, in Ulster, smiths at work, making steel out of the native iron, which they wrought much more easily than it could be made in England. The English and Scotch however, who came over after his report, developed an extensive trade; which seems to have been at its maximum at the time of the rising in 1641.

The Iron-works were of different kinds: some Iron-masters had furnaces and mills; others, especially in Ulster, smelted the iron in bloomeries at the places where the timber was most plenty; while others had their furnaces near the coast of Ulster, Connaught, and Munster, importing most of the ore from England and Scotland. The principal Iron-masters at this time, whose names are recorded, were—Lord Cork, furnaces, mills, and mines in divers places in *Munster*; Wandsworth (Wandesford), furnaces, mills, foundry, and mines, *Carlow* and *Kilkenny*; Sir Charles Coot (Coote), mines and works, *Queen's County*, *Leitrim*, and *Roscommon*; Lord Londonderry, mines and works, *Queen's County*; Lord Ely and Piggot,[1]

[1] Piggot's works may have been in the Queen's County.—(*See* description, King's County, page 285).

mines and works, *King's County;* Sir John Dunbar and Sir Leonard Bleverhasset (Blennerhasset), mines and works, *Fermanagh;* London Company, mines and works, *Clare, Limerick (?);* Sir William Petty, works, *Kerry;* Lord Stafford, mines and works, *Wicklow* and *Carlow (?);* Rennie, mines and works, *Londonderry* and *Tyrone;* and Sir Walter Raleigh, mines and works, *Waterford.*

Boate states that the large furnaces and works, except those on the coast-line, were each built convenient to a mine; while the bloomeries were moved from place to place, where the fuel was most abundant. We may therefore suppose that formerly iron-mines existed close to most of the above-mentioned furnaces.

The majority of these iron-works were destroyed in 1641, during the troubled times; but many of them were afterwards reinstated, while other works and mines were also started.

Later in Wicklow an Englishman of the name of Bacon erected works at Shillalagh, and introduced the importation of pig-iron from Wales. These works were carried on by his son-in-law Cholmondeley, who changed his name to Chamney, and the latter, or his descendants, are said at one time to have had fifty-two works, between founderies, mills, furnaces, and bloomeries, in the counties Wicklow, Wexford, and Carlow; the Chamneys, besides importing ore, worked mines in different places. In Cork, at Coomhola and Roaring Water, were the mines of the Whites. In Clare and Galway, the Bradys of Raheen, the Burkes of Marble Hill, and others, opened new mines and established works; while in Mayo, the Gildeas of Port Royal were large Iron-masters. There were also elsewhere mines and works, that sprung up, to die out subsequently, as the forests were gradually exhausted. At the present time the Bog-iron-ore is exported from Donegal, Londonderry, and elsewhere, to be used in the purification of gas. The raw product, in itself, is of little value; but after it has taken up the gas impurities the "Gas Wastes," as it is called, is so valuable that the exporters find it profitable to supply, free of cost, the Gas, on the condition that they are returned all the "Gas Wastes." The latter are used for the manufacture of very pure sulphuric acid and brown paint.

Coal must have been worked at a very early time in Antrim,[1] but the English were the first to discover and work it elsewhere. Between 1630 and 1640 coal was discovered by Christopher Wandesford at Idrone in the Co. Carlow, while rising iron-ore; subsequently (1728) it was looked for and found in Coolbawn Hill, Co. Kilkenny; but it was not till later, when the woods began to be exhausted, that elsewhere it was more generally looked for and found.

The geological sketches at the beginning of each county description are necessarily very brief, and many important details have had to be quite ignored.

ANTRIM.

The rocks of this county belong to the *Cainozoic*, *Mesozoic*, and *Palaeozoic Periods;* but the exact groups to which the first and last belong have not been determined. The oldest rocks are metamorphosed, and may possibly be of *Ordovician age*, but probably are *Cambrian*. Next to them are rocks belonging to the *Calp* group of the Carboniferous, while the Mesozoic is represented by portions of the *Trias*, *Jurassic*, and *Cretaceous*. The Cainozoic consists nearly solely of sheets of Doloryte and their adjuncts, and in the latter are plant remains, that, some say, indicate a *Miocene*, others, an *Eocene* age. The mines worked have been principally for coal and iron, while at the present time alum-clay (*alumyte*) is also a source of industry.

In the Eocene (?) are beds, or portion of beds, of coal (*lignyte*). alumyte, litomarge (*ferriferous clay*), bole (*aluminous limonite*), and iron-ore (limonite and magnetic); with steatyte, near the Gobbins Island Magee. Various attempts have been made to work the lignyte profitably, but all seem to have failed. In the alumyte works (although in some of the mines there is a considerable thickness of lignyte) it is considered perfectly valueless, and is run out on to the attals (*spoil*, or *waste heaps*), or is used as filling stuff in the old workings (*stulls*).

The probable origin of the alumyte (alum-clay) has been given in a Paper on the "Irish Crystalline Irish-ores," *Scien. Proc.*,

[1] The coal mines in Antrim seem to have been the oldest in England, Scotland, or Ireland.—(*See* Co. Antrim, page 264.)

R. D. S., vol. IV., 1884, p. 311, and need not be here re-given. At the present time only this clay is worked for the manufacture of alum, although the associated lithomarge and bole are very similar in aspect to the ferriferous varieties of the French and German clays (*beauxyte* and *woeheinyte*). It would, therefore, appear expedient that the bole and lithomarge should be more minutely tested, especially the light-coloured varieties of the latter.

The mining in the alum-clay (*alumyte*) is quite of recent date. Its value was first discovered by Mr. Walter Jemerson in 1873, who began to work it in 1874: since then the trade has largely developed.

The following are analyses of the alumyte, beauxyte, and woeheinyte, procured through Mr. Jemerson:—

	Alumyte. Glenarm.	*Alumyte.* Ballintoy.	*Beauxyte.* Dahm's.	*Beauxyte.* Margeilleo.	*Woeheinyte.*
Alumina,	42·45	52·37	63·19	67·83	57·04
Peroxide of Iron,	1·54	1·29	3·72	00·47	1·08
Lime,	0·46	0·48	—	—	—
Magnesia,	Trace.	Trace.	—	—	—
Potash and Soda,	0·04	0·06	—	—	—
Silica,	27·50	13·15	11·47	10·64	19·60
Titanic Acid,	9·40	5·20	—	—	—
Sulphuric Acid,	0·08	0·35	—	—	—
Phosphoric Acid,	None.	None.	—	—	—
Organic Matter,	Trace.	Trace.	—	—	—
Combined Water,	18·53	27·13	16·32	15·80	17·45
	100·00	100·03	—	—	—

The analysis of the alumyte was made by John Pattison, Newcastle-on-Tyne. In the French and German analyses the alumina is both hydrated and anhydrous. As sulphuric acid, in the process of alum making, only extracts the hydrated alumina;

in the continental minerals, by all known processes, there is a loss of from 6 to 8 per cent. that cannot be abstracted ; on this account the Irish clays compare much more favourably with the continental than the Table suggests. Many of the beauxytes and woeheinytes contain much more iron than the above, iron having been made from a variety of the latter. Of beauxyte Dana gives three analyses; containing of iron respectively, 27·6, 3·0, and 34·9 per cent. The Irish clays contain much more silica than is found in the French or German. The Beauxyte, however, which gave 3·0 Iron is white in colour and gives 21·7 of silica.

The Canizoic (*Eocene ?*) iron-ore trade is also of recent development. In 1609 Chichester mentions ore, while in 1683 Dobbs uggested that it existed in Island Magee ; but it would appear that it was not generally known before 1861, when Dr. Ritchie specially directed public attention to those iron-ores. Afterwards they were successfully worked, until the slack in the iron trade, since which time, although not as successful as previously, there is a sufficient demand for the ore to keep some of the workings still going.[1] The occurrence of the pisolitic-ore is peculiar ; for, although it appears as if bedded, its genesis probably was long subsequent to the formation of the associated rocks. The pisolitic iron-ores fill horizontal shrinkage fissures, the accumulations having characters more or less analogous to those of standing lodes.—(See *Scien. Proc.*, R. D. S., vol. IV., 1884, p. 312.)

The steatyte at the path to the Gobbins Island Magee was formerly worked as "French chalk."

In places the doleryte is decomposed into a rich ochre. Of ochre found at Mr. M'Arthurs, near Ballymena, Apjohn writes : "The silex of the basaltic ochre is at present in a state of extreme division; and from this circumstance, and the great depth and beauty of its colour, it appears well suited to the purpose of a red paint for gates, railings, and other descriptions of outdoor work.

The Jurassic beds (*Lias*) are very sparingly represented ; but in them are apatitic nodules (*phosphates*). These, however, have not been found in sufficient quantity to be utilized.

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[1] Quite recently (1885) arrangements have been made to work an accumulation found in Rathlin Island.

In the Trias, near Cushendall; in the Forth River Valley; in the Woodburn Valley, between Kilroot and Whitehead; and in the Valley of the Lagan, gypsum occurs in the marls; but although the veins in places are numerous, none that are known are thick enough to pay for working.

The Salt mines at Duncrue are of recent date, the salt having been discovered in 1850 while boring in search of coal. As mentioned in Part I., page 252, the *Salt Measures* may extend eastward towards Eden, and northward towards Larne, as saline wells are found in those directions.

In remote and recent years there have been workings for coal and iron in the BALLYCASTLE COAL-FIELD. The rocks are commonly called Coal Measure; but correctly they are a portion of the Calp division of the Carboniferous limestone: they are, however, the equivalents of the so-called "Lower Coal Measures" of Scotland. The earliest works were during the time that "stone implements" were in use, as about 1770, during the mining operation, then in progress, old galleries, having in them wicker-work baskets and stone implements, were broken into. In recent years the Macgildowneys were those who worked the coals, the royalties at the time belonging to the Boyds.

At what time, or by whom, the ancient galleries were driven is now unknown; but it is evident the industry ceased and was forgotten. In 1700, Ballycastle[1] was quite a poor place, containing some sixty-two house-holdings, and extending over an area of about three acres. But about the year 1784 it had advanced, and became a prosperous town, having its iron works of various kinds, its manufactures of salt and soap, its weaving and bleaching establishments, its tanyards, its glass-house, and brewery. The enumeration of these is in part foreign to the present inquiry; but as they were in a great measure adjuncts of the mining operation, it may be allowable to refer to them.

The prosperity of the place was in a great measure due to the energy of Hugh Boyd, the proprietor, and it began to decline about 1670 or 1680, after his death, the decline being aided by

[1] This place got its present name from the castle built in 1609 by Randolph, Earl of Antrim. Correctly the coal and iron works should be called the Culfeightrin collieries; but this name has been quite superseded by that of Ballycastle.

the London Society (Londonderry) having successfully opposed a grant of money to improve the port.

It may be mentioned that the glass industry seems to have been of a very ancient date, possibly prehistoric, as some authorities suggest that this was one of the places in which the ancient glass beads and such like were made. It was induced by the excellent sand of the vicinity, due to the weathering and washing of the sandstones of Carboniferous age. The glass trade, which was principally an export one to Scotland, gradually declined as the native coal increased in price, and seems to have finally ceased in 1850, or thereabouts, when the glass-house was destroyed by lightning.

The higher coals, or those above the level of the sea, are worked out. There are, however, two coals, called the "sea-coals," below the sea level, still unwrought; which have been estimated to contain about 18,000,000 tons of coal; but as far as trials have been made they are unprofitable, on account of the drainage of the sea into the workings: very little, therefore (if any), of this coal can be profitably raised.

Mr. Knowles of Ballymena has found prehistoric beads made of *zoisite*, or *jade de saussare* (saussaurite), in the Æolian sands in places along the coast-line in connexion with Kitchen midding and such like early traces of man; while Mr. M'Henry has discovered small veins of similar jade in the metamorphic Cambrians (?).

In, or associated with, the older rocks (*Metamorphosed Cambrians?*) gold is said to have been found in Glendun, near Cushendun; and in 1825 the Glenarm and Antrim Mining Association proposed to work the gravels of the river. This Company are also reported to have found in Slieve-an-orra and neighbouring hills, traces of copper and lead; but the extent to which they carried their researches in quest of these minerals is uncertain, as there are not any published records of the places where these minerals were found.

As already stated, in this county was situated one of the three lead mines discovered by the English prior to the rising of 1641; whereabout it was situated Boate does not state, but he gives a most glowing description of it, stating: "for as much as with every thirty pounds of lead it yielded a pound of pure silver." At the present time it is quite unknown.

In the National Museum, Leinster House, Dublin, are some fine specimens of Onyx, said to have come from Rathlin Island.

Armagh.

The major portion of this area is occupied by *Ordovicians* in part metamorphosed with which to the S. E. are associated *Granyte* and allied rocks. These to the N. W. are succeeded by *Carboniferous* limestone, while the latter, at the N. W. of the county, are overlaid by *Triassic* sandstone or marl, and to the N. E. by the *Tertiary* or *Cainozoic* rocks or the *Lough Neagh* beds. Some of the rocks near Armagh and to the N. E. at Benburb have been said to be *Permian:* their position and fossils, however, seem to prove this conjecture to be erroneous.

The recorded minerals occur nearly solely in the *Ordovicians* or the associated *Granyte* and allied rocks. The principal mineral in the lodes was lead, but copper occurred in the veins at Jerret's Pass, near Newry, and Tullydonnell, near Crossmaglen. Griffith records an ancient mine at Ballymore, near Pointzpass, but states its "exact position is not ascertained."

Lewis reports antimony as having been "found in a few spots."

Westward of Slieve Gallion in the western slopes of the hill near Larkin's mill, and not far from the edge of the Granyte, either *Steatyte* or *Pyrophyllyte*, probably the latter, has been found.

Carlow.

The major portion of the area, included within the limits of Carlow, is occupied by *Granyte*, a part of the Leinster range. To the extreme S. W. of the county is a small tract of *Coal Measure* a portion of the Kilkenny Coal-field, which lies on the *Carboniferous* limestone of the valley of the Barrow, the latter overlapping the Granyte. These limestones are supposed to lie direct on the Granyte; but a few small outlyers of Carboniferous Sandstone have been found, which may suggest that elsewhere rocks of this class intervene, but are unknown, being obliterated by the envelope of Drift.

Farther northward, in the Co. Kildare, Metamorphic rocks (*Ordovicians*) intervene between the Granyte and the Carboniferous rocks, but they do not extend southward into the Co. Carlow; to the eastward of the range, however, at Clonegall and Newtownbarry a tongue of these rocks extends from the Co. Wexford into this county.

This county does not appear in Griffith's lists; but in the Coal Measure there are some seams and nodular beds of clay-iron stone that were mined between 1600 and 1641 by Christopher Wandsworth (Wandesford); who had also works, including a foundry for ordnance, at Idrone.—(See *Leinster Coal-field, Co. Kilkenny*). In latter years iron was raised near Shillalagh, Co. Wicklow, and probably also in this county.

Except the clay-iron stone there are no authentic records of minerals or veins. Gold, indeed, is said to have been found not many years ago in one of the valleys N. E. of Graguenamanagh: this has not, however, been authenticated. Lead is also said to have been found in one of the same valleys, and some trials were made unsuccessfully. It may be pointed out that these trials were injudicious, and not in the places where lodes would probably be found.

Cavan.

About Lough Sheelin, at the south of the county, and extending in from Westmeath, is the edge of the great central tract of *Carboniferous Limestone*, while in the vicinity of Stradone there is a small outlier. The north-western portion of the area is solely occupied by Carboniferous rocks; in places there being *Coal Measure;* as in a small tract between Ballyconnell and Swanlinbar; and in the hill country, to the N. W., of which Cuilcagh, partly in Leitrim, is the highest summit. At Cavan there is a limited tract of *Carboniferous Sandstone*, and S. W. of it is an intrude of *Granyte*, while the rest of the area is occupied by *Ordovicians.*

The mountain tract to the N. W. is a portion of the Connaught Coal-field; including portions of the counties Cavan and Fermanagh (*Province of Ulster*), with parts of Sligo, Leitrim, and Roscommon (*Province of Connaught*). As all are part of the one field, they may here be described together.

In old times, but more especially in the sixteenth and seventeenth centuries,[1] there was extensive mining, smelting, and milling, of iron, which lasted till the woods were exhausted, the fuel being wood-charcoal. As the woods disappeared the fires were put out, the last extinguished being Drumshambo, Co. Leitrim, in 1765. Shortly afterwards, in 1788, the three brothers O'Reilly tried to revive the industry, and smelt the iron ore with the coal—the first attempt of the kind in Ireland. They erected a furnace and mills at Arigna, Co. Roscommon, and sent into the market some excellent pig and bar iron; the coal being procured at the Rover and Aughabehy collieries; respectively, about one and three miles distant. The adventure, however, did not prove successful on account of English competition; and after passing through the hands of other speculators the enterprise was abandoned in 1808.

In 1818 Griffith made a favourable report of the iron ore of the district: this, coupled with his statement before a Committee of the House of Commons in 1824, induced the Irish, the Hibernian, and the Arigna Companies to take setts for the working of coal and iron in the Co. Roscommon. The first and second had their mining setts in the Cashel Mountain, or Slieve Curkagh, the range of hills north of the Arigna River; while the workings and works of the Arigna Company were to the southward of that river in the Bracklieve range; but now more generally called the Arigna Mountain, after the name of the site of the furnace and mills. Practically the Hibernian Company did no work, the report of their surveyor being considered unfavourable. The Irish Company opened some pits, the largest being at Tullytawen, where the coal for a time gave a profit; but the most extensive works were those of the Arigna Company.

The original works of the O'Reillys at Arigna appear eventually to have become the property of the Latouches of Dublin, because from them, in 1824, the new Company obtained a lease of the works and mines. They commenced work with a large staff of

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[1] Before the rising in 1641, Sir Charles Coote, besides his Iron Works at Mountrath, Queen's County, had others in the counties of Leitrim and Roscommon. The Leitrim Works may have been at Creevelea, and those of Roscommon were somewhere in the valley of the Arigna, all these works were burnt in 1641.

English artizans and engineers, and from November, 1825, to May, 1826, the works were prosperous, some 250 tons of iron being manufactured at a cost of £8 4*s.* per ton. Then unfortunately, through some mismanagement, the furnace was choked; which led to an expensive Chancery suit, lasting for ten years, when it was decided in favour of Mr. Flattery, who recommenced the smelting and manufacture of iron in 1836. Flattery worked for some years very spiritedly, opening, besides O'Reilly's collieries, another at Gubberudda, where the coal was of a better quality. But eventually he could not compete with the English and other iron-workers, and his fires had to be put out. Since Flattery's time iron has not been smelted in the district, but the coal has been worked profitably for a local trade.

In the Slieve-an-ierin district, to the east of Lough Allen, counties Leitrim and Cavan, the clay-iron stone is richer than in Co. Roscommon, and in former times, while the forest lasted, was extensively mined and worked, the name of the hill *anglice* "mountain of iron," suggesting pre-historic workings. Since the Drumshambo furnace was put out, in 1765, no iron has been smelted, while very little work has been done in the coal, apparently on account of the great quantity of peat fuel. According to Boate, iron was worked, in 1650, "in a place called Doubally," Co. Cavan, and "upon Lough Erne," Co. Fermanagh.

To the N. W. of the Co. Leitrim, in the barony of Drumahaire, the clay-iron-stone was formerly also extensively raised. Of this a considerable quantity was carried to Ballynakill, south-east of Colloonoy, and to a furnace near Ballysodare, both in the Co. Sligo, to be mixed with other ores and smelted. It was also smelted at the Creevalea Iron Works, townland of Gowlaun. In this townland, and the adjoining one of Tullynamoyle, there are various beds, or nodular beds, of clay-iron-stone, the richest, as pointed out by Griffith and Jukes, being one about eleven inches high, which is as good, or perhaps better, than any of the seams in Slieve-an-ieran. According to the record, Sir C. Coote appears to have had works here in 1640, while the last furnace for smelting iron with wood-charcoal, was extinguished in 1768. The works, however, were resumed, in 1852, by a Mr. Currie, who, laid out large sums in blast furnaces, kilns, tramways, engines, and workmen's houses; but became bankrupt in 1854. Afterwards the works were rented by

Mr. Potts of Dublin, who smelted a little iron with peat charcoal; they, however, were abandoned in 1858–59.

In this field the amount of clay-iron-stone is considerable: some of it, however, is inferior. Of coal there cannot be much; perhaps some 10,000,000 tons, of which only a portion could be economically wrought, especially during the present low price of coal and high rate of wages. The coal in part is gaseous.

Other minerals in Co. Cavan occur in veins in the *Ordovicians*, such as copper in Farnham, near Cavan, and lead near Cootehill, Shercock, and Ballyconnell.

In the *Ordovicians* of Kill, near Kilnaleek (*sheet* 37), there is a bed of anthracyte. This, when discovered in 1854, was sank on, and according to Dr. Whitty's report, was in one place four feet thick. This, however, appears to have been a local swelling of the bed, as elsewhere in the strike and in depth it was only a few inches wide. About two miles southward of Shercock are beds of anthracitic shales: these in bad winter, when fuel was scarce, have been worked for fireing; they were, however, only a make-shift in the place of better, because at present they are of no commercial value. It is, however, possible that here, as in Canada, anthracitic and carbonaceous shales may point to underlying oil or gas cisterns. This seems worthy of further research.

Clare.

The rocks of this county belong to the *Carboniferous* and *Ordovician* periods. Nearly half the western portion of the area is occupied by Coal Measures, the northern portions of the extensive West Munster Coal-field; while to the east, in the neighbourhood of Lough Derg, hills of Ordovician rocks protrude up through the Carboniferous.

In Munster, especially Limerick and Clare, below the *Calp* and *Fenestella limestone* (lithologically divisions of the Carboniferous rocks) leady lodes often occur; below the Fenestella limestone the lead is usually accompanied, more or less, with copper and sulphur ores. On both horizons the minerals do not occur in regular lodes, but in pockets and "shoots," which, when worked out, have no leaders to other deposits. Different, very rich pockets

have been found on both horizons, which were remunerative to the first adventurers, but more or less disastrous to their successors who have attempted to follow what they supposed to be "leads." Pockets of this class are indicated by calcspar, associated with dolomitic sand. In the limestones of the *Burren type* numerous small veins of lead and zinc have been found, but none of them of promise; yet we learn from the records that, in the time of James the First, there was a "silver-mine" in the Burren, adjacent to O'Loughlin's Castle, now called Castletown, while there are misty records of much more ancient mines. Fluor or fluorspar was found in different mines, associated with the lead,

In the *Coal Measures*, near the Shannon, below the horizon of the lowest coal, some of the shale-beds are very rich in nodules of clay-iron stone. The coals in this county are of very little account. Near the Shannon, to the south, there are some thin beds, that were worked in old times along the outcrops, but as they are traced northward they thin, till eventually the horizons are only marked by fire-clays, with stems of stigmaria. The iron-ore beds also appear to become poorer as they are followed northward. In the old times the latter were worked to the southward, in the vicinity of the estuary of the Shannon. Some of this ore seems to have been smelted in the vicinity of the mines, but much of it was carried inland, or was sent up the Shannon by boats, to be mixed with Ordovician and other ores at the furnaces on Lough Derg or elsewhere. This clay-iron stone is mentioned as worked in 1650, while it was smelted and wrought by a London Company at furnaces and mills near the mines.

Iron ore in the Ordovician rocks was extensively raised in Glendree, westward of Feakle, also at Ballymahon and Bealkelly, near Tomgraney. East of Feable, at the hamlet now called Furnace, are the remains of considerable works, apparently principally for smelting purposes; while the iron raised at the mines near Tomgraney is said to have been sent by boat, to be smelted and milled at the different furnaces and works between Mount Shannon, Clonrush, and Woodford, west of Lough Derg, Co. Galway. According to the records, three classes of ore appear to have been in use for mixing at the furnaces, and these, from Gerrard Boate's descriptions, were evidently the bog-iron-ore, the ore from the Ordovician rocks, and the clay-iron stone from the

south of the county and the Co. Limerick. These furnaces and mills were at work until the woods were exhausted; the last fire put out (Woodford), about the year 1750, belonged to the Burkes of Marble Hill.[1]

In the *Ordovician* rocks in different places are found, besides the iron ore (limonite), small veins and indications of lead, sulphur-ore, copper, anthracite, plumbago, &c.; but up to the present time none of them have been worked very successfully.

Cork.

The rocks of the premier county of Ireland are both interesting and peculiar. North of the valley from Dingle Bay, Co. Kerry, to Dungarvan, Co. Waterford, there is one type of Carboniferous rocks, while south of that line there is another. In the north-west part of the county, in the Ballyhoura and Galtee Mountains, there is *Carboniferous Sandstone*, within the latter a small exposure of *Ordovicians*. Over the sandstone lies the *Carboniferous Limestone*, and on the latter *Coal Measure*, a part of the West Munster Coal-field.

But south of Dingle Bay and Dungarvan Valley the rocks have lithological characters, more or less peculiarly their own, which have lead to various classifications and nomenclature. The petrology, or the *geological relative positions*, of the different groups have been very successfully worked out by Griffith and Jukes; but to suit the present ideas their names require revision, or rather modification. In this area there is very little limestone, it only being found to the eastward, while elsewhere it is replaced by shales, slates, and grits (*Carboniferous Slate*); these towards the west are of considerable thickness, being much thicker than the Carboniferous

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[1] In the *Geology of Ireland* (1878), chap. xxi., p. 352, and in other writings on the subject, I have suggested as probable that the last furnaces in which wood charcoal was used for smelting iron were those of Woodford in Galway and Port Royal in Mayo. Since then I find that the Port Royal works appear to have been in existence subsequent to those of Woodford; while in Leitrim and Sligo there were fires alight in 1765 and 1768, or nearly twenty years later than at Woodford. The fires at Shillalagh, Co. Wicklow, were put out a few years before Chamney's death, which took place in 1761. The Port Royal works seem, however, to have been more recent than those of Sligo and Leitrim, as, about the year 1860, the old mill was partly in existence, the forge anvil being still *in situ*.—(*See* Mayo, p. 290.)

Limestone of the Central plain. Under the Carboniferous Slate is the *Yellow Sandstone* (Griffith) or *Upper Old Red Sandstone* (Jukes): it graduating downwards into the *Devonian* or Lower Old Red Sandstone, and the latter into the *Glengariff Grits* (Jukes) or *Silurian* (Griffith). The equivalents of the groups, as nearly as possible, are as follows:—

	Cork Type.	Central Ireland Type.
4.	*Carboniferous slate*, . . .	Carboniferous limestone and Lower limestone shales.
3.	*Yellow sandstone*, . . .	Lower carboniferous sandstone.
2.	*Devonian*, or Lower Old Red Sandstone,	Lower Devonian (?) (England).
1.	*Glengariff Grits*, ...	Silurian.

The Glengariff Grits are evidently the representations of the upper beds of the Silurians of the Dingle promontory, Co. Kerry. The Devonian (*Lower Old Red Sandstone*) are in part the equivalent of the Lower Devonians of England. In Co. Cork they form a regular *unbroken passage* from the Carboniferous rocks down into the Silurian; but in Slieve Mish, Co. Kerry they are only in part represented, the lower strata being absent, while the higher ones lie direct, but unconformable, on the Dingle Silurian.[1] Elsewhere in Ireland, except, perhaps, the Fintona Mountains, counties Fermanagh and Tyrone, the Devonian rocks are not represented.

The Yellow Sandstone (*Upper Old Red Sandstone*)[2] is an im-

[1] In Slieve Mish, above the unconformability ("Inch or Park conglomerate"), and below the Lower Limestone Shales, there is a thickness of some 5000 feet of strata. These must represent part of the rocks (called by me Devonians) below the Carboniferous Slate, Co. Cork. This fact seems to be ignored in the proposed new classification of the Cork rocks.

[2] Jukes' names for the Cork rocks, *Upper and Lower Old Red Sandstone*, has been the cause of considerable controversy in the Mining Community, they apparently not understanding that they are petrological or group names, and do not specially refer to lithological characters, and that the rocks of the groups may be either argillaceous (*shales and slates*) or arenaceous (*sandstones*). In Jukes' groups, as a general rule, argillaceous rocks (*Killas* of the miner) are more prevalent in the Upper, and arenaceous rocks form the majority in the Lower. In the Yellow Sandstone, or *Upper Old Red*, of the Co. Cork most of the Copper veins occur, they not being of any value in the Lower Old Red.

portant group, as at its base are the *Metallic schists* and their associated copper lodes.

The above divisions appear to be the true natural grouping of the South Cork rocks. Of late another, of a lithological character, has been attempted; but both petrologically and palæontologically, and even in part lithologically, it is evidently incorrect.

In the extensive West Munster Coal-field, only in this county, have productive coals been found; while here they seem solely to occur in a narrow strip along the Blackwater valley. In this strip the coals stand at a high angle, and appear to be cut off in depth by nearly horizontal faults. On this account, unless an elaborate system of bore-holes were put down, it is perfectly impossible to even guess, at the quantity of unwrought coal. The coal (*anthracite*) is of two distinct qualities—hard and soft—the soft flakey kind, or *culm*, being greatly in excess of the hard and more valuable variety. The latter is very sulphurous, but gives a strong heat. These coals have been working continually for a century and a-half. According to the writings of Gerrard Boate and Smith, clay-iron stone appears to have been raised here, to mix with bog-iron and the Devonian ores, for smelting at the furnaces presently mentioned.

In the Carboniferous Limestone and Sandstones, only a few mineral lodes are recorded.

In the Devonians, however, in the seventeenth century there appears to have been a large iron industry. During the time Sir Walter Raleigh lived at Youghal, he was an iron-master, having mines and works in the Devonians, Co. Waterford; but it seems uncertain if he did any work in this county. Lord Cork, however, had works in divers places. Smith, writing in 1750, mentions Lord Cork's works at Araglin, near the eastern extremity of the county, and those of the Whites, at Coomhola near Glengariff, and Aghadown near Roaring-water bay. Boate, a century earlier (1652), states that Lord Cork's works were near Tullow Bridge, and the ores used were of three kinds—bog-iron ore, clay-iron stone, and limonite or hematite—the latter probably being raised in the Devonian rocks.

During the present century there has been considerable copper-mining, induced principally by Colonel Hall's discovery, in 1810, of a valuable lode at Allihies (*Berehaven Mines*). These lodes occur in

the *Metalliferous beds* at the junction of the Yellow Sandstone and the Devonian rocks, and whenever they passed out of the Metalliferous beds, either horizontally or in depth, they became valueless. Here the strata occurred advantageously, being in a half bowl, across which the lodes (*counter lodes*) ran both E. and W. and N. and S. Some of the continuations of the lodes at the surface are massive, but, unfortunately for the Mines, once they pass the limits they lose their copper. These lodes at the first produced large returns; but after 1860 they began to fall away, and now appear to be nearly valueless.[1]

Elsewhere, in the south of the Co. Cork, there are a few *counter lodes;* but most of the copper and other lodes run more or less with the strike of the rocks, only cutting across the beds in depth. On this account they are not so productive; nor are they so continuous in depth; because, when going down, if they have to pass through one of the massive grits, they split up into strings, and nearly invariably die out. It has been suggested that if these massive grits were sunk through the lodes would again be found: this, however, seems improbable, because, in some of the cliff sections, it can be seen that such split-up veins do not again mass into one. Some of the so-called lodes are regular beds of killas, highly impregnated with grey copper ore. In different places rich pockets have been found close to the surface, while in depth the lode lost its minerals. As pointed out by Jukes, the copper is very widely disseminated in the rocks, and "it will be obvious thata large quantity of poor ore, easily accessible, may be more productive than rich ore, or even the metal itself, which is disseminated in small quantities, or in situations requiring great trouble and expense for its extraction." In this portion of Cork the lodes are very deceptive, and it "is a district where, perhaps more than others, requires great caution, as well as skill and prudence to mine with profit, and is a most delusive district to the speculator, from its containing so many of these specimens of rich ore, many of which have not indicated the existence of much more ore than was actually seen in the specimens."

In the *Metallic shales* of the Yellow Sandstone the prevailing

[1] On account of the Igneous rocks in the vicinity (*Cod's Head,* &c.) it is possible, if tried in depth, *Tin* might be found.

ores are yellow and grey copper; but when passing from these into the Carboniferous Slate, and also in the latter, the ore is principally lead. There are, however, associated with the copper ores, the ores of various other minerals (*see* LISTS) enumerated in Part I.

A peculiar lode occurs at Glandore and at Rosscarbery. It is associated with a dyke of fault-rock, and has a back of iron ore—in the latter fissures formed, which are now filled with manganese ore. It has been worked both for the manganese and iron, but has not been proved in depth. Probably it is a coppery lode.

Within the last few years there has been a movement in favour of the West Cork mines, especially those in the Sheeps Head promontory. Near Kilcrohane, and north-eastward thereof, there have been workings on the large coppery sulphur-ore lodes, and on some of the bedded grey copper lodes. In these lodes there is a considerable quantity of arsenic ore (*arsopyrite*), and in places the carbonate and oxides of copper occur, as profitable "backs" to the lodes.

There are in some localities large accumulations and veins of barytes, while the copper ores at Dhurode (*Carrigagat*) and Kilcrohane (*Sheeps Head*) are auriferous, while the grey copper ore of Lissaremig and Rooska is argentiferous. With the silver-copper there is also silver-lead, while in the old workings at Rooska they raised a considerable quantity of carbonate of iron (*Chalybite*), which still remains in the *attals*, or waste heaps.

Anthracite is stated to have been found at Twomilebridge and Strancally, near Youghal.

Very good amethysts have been found in places in the Devonians, and were formerly utilized.

DONEGAL.

The principal portion of this county is occupied by Granitic and Metamorphic rocks, they having in places on them small patches of *Carboniferous Sandstones, Shales, and Limestones.* The Metamorphic rocks, in 1884, were discovered by the late Gerrard A. Kinahan to belong to two geological periods, the younger are Ordovicians, and the older *must be either* Cambrians or Laurentians.

It is not only absurd but also frivolous, to draw in them imaginary boundaries, and call a part Laurentian and a part Ordovician, as has been proposed. The larger portion of the Granyte is intrusive, but associated is some Metamorphic Granyte, and a considerable area of Granitic gneiss.

Since the beginning of the present century various explorers have published lists of minerals; but, although examined by so many, only a few valuable mines have been discovered. Some good silver-lead was found in the Carboniferous Limestone near Ballyshannon, and in Metamorphic Limestone at Killdrum, to the south-westward of Dunfanaghy; elsewhere there are not any metal mines of note, although in places there are very fair-looking indications. At Carricknahorna, near Ballyshannon, there is a lead lode with a "back" of iron and manganese in the Carboniferous Limestone: this was worked for the iron-ore in 1884; and 30 tons of ore was shipped for Ballyshannon, to Mostyn, on the River Dee, by Messrs. Fathem and Kidd.

Cainstone, or *pyrophyllyte*, has been recorded in a great many places, and the harder varieties were formerly used for architectural purposes, while the finer kinds have been mined and sent into the market as *steatyte*. Thin beds of anthracyte are recorded as having been found at Dromore and Kintale, on Lough Swilly; while gold is said to have been detected in a small quartz lode in the stream that flows from Lough Knadas, one mile due east of Ballyshannon.

As long as the forests lasted iron was largely smelted, and the remains of the bloomeries and mills are found in different places. Some bog-iron, and perhaps other native ores, were used; but the records state that large quantities of ore were imported into the country from Scotland and England. At the present time there is an export trade of bog-iron-ore, to be used in the process of cleaning gas.

Very fair beryls occur in some of the exogenous Granyte veins S.E. of Dungloe, at Doocharry, and Slieve Snaght, barony of Boylagh; while Giesecke reports having found greenish-gray jade at Crohy, in the same barony.

Down.

The area within the limits is nearly solely occupied by *Ordovicians*, which towards the south are in part metamorphosed, having associated with them Granitic rocks of different ages—Ordovician, Triassic (?), and Eocene (?). At the extreme south of the county, also in the neighbourhood of Castle Espie, N.W. of Strangford Lough, are very small tracts of *Carboniferous Limestones.* On the shore of Belfast Lough is a small exposure of dolomyte, having fossils of *Permian* types; while in the valley of the Lagan, to the N.W. and W. of the county, the *Trias* is capped with *Cretaceous* and *Eocene* (?) rocks.

In the Cainozoic rocks are thin, valueless beds of lignyte, and in the Trias gypsum, but in too thin veins to be valuable.

In the Ordovicians are numerous small veins and indications of lead and copper, but only in a few places have they been found rich enough to work. A few thin beds of anthracyte have been noted in the vicinity of Strangford Lough.

In early times iron was mined in the Slieve Croob district; and a few years ago good hematite was discovered at Deehommed, south of Banbridge: this mine has still to be developed.

In exogenous veins in the Triassic (?) Granyte of the Mourne Mountains topazs and beryls have been procured; the localities being the N.W. side of the small lake on Bingian, on Slieve Havila, and the Chimney Rock Hill.

Dublin.

In this county the prevailing rocks are *Carboniferous* of the Calp type. At Howth and Bray are small tracts of *Cambrians.* West of the latter is the N.E. extension of the Leinster Granyte range, flanked westward by *Ordovicians*, in part metamorphic; while at Portraine and Balbriggan there are small exposures of *Ordovicians.*

The county is poor in mines, the lodes found, being principally lead and copper. In the Granyte at Dalkey, tin is also recorded by Griffith.

Rich silver-lead, with silver, was found to the south of the county, at Ballycorus, and lead at Shankhill and Rathmichael, at the vicinity of the junction of the Granyte and Metamorphic rocks. These lodes are worked out, but other lodes ought to occur elsewhere in the vicinity of the line of junction.

Gold in small quantities has been found in the Diluvium of some of the valleys in the Ordovician.

Beryls have been found in the neighbourhood of Killiney and Dalkey, in Glencullen, on the Three-Rock Mountain, and at Stillorgan.

FERMANAGH.

Westward of the valley of the Loughs Erne the rocks are *Carboniferous Limestone*, capped by *Coal Measures;* while east of that valley there are Carboniferous Limestones and Shales overlying a tract of *Silurian rocks* (Lower Old Red Sandstone). The arenaceous Carboniferous rocks to the eastward were mapped by Griffith as *Calp*, but of late years they have been said to belong to the *Lower Coal Measures.* No good proofs, however, in favour of this change of classification seem to be forthcoming, while they are very similar to the Calp rocks north of the TYRONE COAL-FIELD.

At Lisbellaw, S.E. of Upper Lough Erne, is a small exposure of *Ordovicians;* while to the north and north-east of the same lake are portions of the adjoining tracts of Metamorphic rocks, which may be either *Cambrians* or *Ordovicians.*

Except in connexion with the clay-iron-stone in the Coal Measures, this county is absent from Griffith's list; but since that was published, copper, iron, and molybdenite have been found at Castle Caldwell in the Metamorphic rocks. No mineral lodes have been found in the Carboniferous limestones or in the Silurians; this, however, may be due to the great head of drift, or bog, over those areas.

During the years 1620 to 1641 extensive mining and milling of iron was in progress, the principal works belonging to Sir J. Dunbar and Sir L. Bleverhasset (Blennerhasset). In latter years the iron appears to have been also mined and smelted until the forests were exhausted.

Galway.

Except the north-western portion of the county (Yar or West Connaught), the rocks are principally *Carboniferous Limestones*, with subordinate sandstones and shales; but through these come up detached exposures of *Ordovicians*. Yar Connaught is occupied nearly altogether by metamorphosed *Ordovicians* and *Cambrians*, with their associated *Granytes* and *Granitic rocks;* but on them, to the north, is a tract of *Silurians*.

As it has been stated that some of the Yar Connaught rocks are Laurentians, it may be pointed out that when Murchison some years ago suggested that the oldest rocks of the county, those of the Bennabeola Hills, were of that age, he afterwards found reasons to withdraw his suggestion; while the rocks now stated to be of that age carry fossils of Llandeilo types.

In the Carboniferous Limestones some good and rich silver-lead accumulations have been worked; but unfortunately, as at Caherglassan, near Gort, and elsewhere, on account of the cavernous nature of the rock, and the low altitude of the county, they cannot be profitably worked, the influx of water being too great. Some of the lead mines in the south-east of the county are supposed to be prehistoric, not having been worked since 1640, and probably not for centuries previous.

In the Metamorphic and Granitic rocks are many lodes and indications of copper, sulphur ores, lead, and zinc; some very rich bunches having been already extracted. All the mining operations in the area have been on a small scale, proving the lodes at the surface, but not in depth; and from what is now known it would appear as if at some future time it might be the seat of large and remunerative mining operations, more especially if reducing works were erected in the county, as, on account of the great preponderance of sulphur ores (*pyrite* and *pyrhotite*), the ores in their raw state will not bear the expense of long carriage.

At intervals between 1620 to 1750 iron was extensively smelted and milled in different places along Lough Derg, the last furnace alight being that of Woodford, belonging to the Burkes of Marble Hill. In these furnaces the bog-iron-ore was

in part used; but it was mixed with clay-iron-stone from counties Limerick and Clare, and limonite from Tomgraney, Co. Clare, brought up the Shannon in boats; the furnace and mills being erected hereabouts, on account of the vast forests in the neighbouring hills.

There were also furnaces in places on the western coast: to these foreign ore was brought by sea, to be mixed with the native bog-iron-ore.

The native sulphur found in the limestone at Oughterard seems to be long known, as the ancient name of the river is Owenriff, *anglice* Brimstone River. Blue fluor spar occurs at Juverin, west of Spiddal, while pale-bluish, greenish, and yellowish translucent varieties were found at Glengowla, near Oughterard.

KERRY.

In the south-west of the county, including the promontory of Ieveragh and the Killarney hills, are *Devonians* and *Silurians* similar to those of West Cork (see page 273), having on them, alongside the bay called Kenmare River, *Yellow Sandstone* and *Carboniferous Slate;* but eastward, at Kenmare, these are replaced by cleaved *Limestone* and *Lower Limestone Shale*, or the transition rocks between those of the West Cork types and those of the Central plain types (*West Cork rock*, p. 273).

In the Dingle promontory there are *Silurians* and *Ordovicians.* To the northward and eastward (Slieve Mish) these are capped unconformably by rocks that represent the upper portions of the *Devonian* rocks of West Cork; while further northward in the Kerry Head promontory are similar rocks. The Kerry Head and Slieve Mish Devonians lie conformable under the *Carboniferous Sandstone Shales* and *Limestones* of the low country to the eastward, the latter being capped by *Coal Measures*, a part of the extensive WEST MUNSTER COAL-FIELD.

As has been mentioned, in the *resumé* on Cork, the coals known in the Kerry portion of this field are of little value, while there are small prospects of better being found. In general these are more or less culm, or thin. Not much clay-iron-stone is recorded; some, however, was raised in old times.

In the Carboniferous Limestone silver-lead and silver occur in various places; but, except in the Killarney district, the lodes or strings in general have not been very large. The Killarney lodes have been long known, having been worked in the eleventh century. Nemius, writing at the time, states: copper, lead, tin, and iron were found there. Smith, in his history, also says he found some tin-ore; but in subsequent time it has been unknown, and never was worked.

When working the copper mine at Muckross, in 1794, M. Raspe discovered cobalt, bloom and grey cobalt. After the discovery little remained to be utilized, as all the accumulation, except about twenty tons, had been run into the lake as rubbish. The small portion saved had been surreptitiously carried away by a miner who recognized it as Erythrite (*Kane*).

Near Castleisland there is a slate, called *Lapis Hibernicus*, which was formerly worked and carted to Tralee, to be used in the manufacture of copperas. This industry had, however, to be abandoned, on account of the difficulty and expense of the carriage of the copperas to the nearest market.

In the seventeenth century, on account of the extensive forests, various iron furnaces were erected in places along the coast, to which iron-ore was imported. The Earl of Cork, however, seems to have smelted native ore near the south of the country, while there are also the ruins of furnaces and works at Killarney.

Lewis records copper pyrites as having been found prior to 1837 in Glancrought.

A vein of amethyst of a very beautiful colour, near Kerry Head, was formerly used for jewellery.

Kildare.

This county is situated near the eastern margin of the great central area of *Carboniferous Limestones*, which, to the eastward, except south of Celbridge, seem to lie direct on the *Ordovicians*. South of Celbridge to the east of Ballitore, and in connexion with the Chair of Kildare range of hills are small tracts of *Lower Carboniferous Sandstone*, with an exposure of *Ordovicians* in the last. At the eastern margin of the county, intruding into the Ordovicians, there is *Granyte*.

The county in general is covered by drift, or bog, and only in a few places have mineral veins been discovered. Lead was mined at Wheatfield, near Celbridge, in 1828; while Lewis records copper and iron as having been found in the Ordovician rocks of Dunmurry, near Kildare, in 1786.

No gold is now found in the county; yet tradition has it, that ancient Placers were worked somewhere near Ballymore-Eustace. At one time the Upper Liffey, above Poulaphuca, must have run northward along the flats at the mearing of Wicklow and Kildare to join into the Slaney at Baltinglass; and it is possible that somewhere in these ancient river-gravels the traditional Placers were situated.

In the counties Dublin, Wicklow, and Wexford, to the eastward of the Leinster Granyte range, in the Metamorphic Ordovicians, are mineral veins; while, as pointed out by previous writers, none have been found in the similar rocks westward of the Granyte, except the iron vein in Glenasplinkeen, Co. Wicklow. This possibly may be due to the deep limestone gravel, extending from the plain up unto the Granyte, often to the height of 400 feet, and in places to 500 feet or more, thus preventing the Metamorphic rocks being properly seen or examined; as eastward of the range, where the mineral veins have been found, these drifts rarely occur above the 250 feet contour line. Similarly in the Co. Wexford, to the eastward of the range, where the rocks are more blinded by this drift, the mineral localities known, are fewer than in the Co. Wicklow.

Kilkenny.

To the south-east of the county there is an area of *Ordovicians*, having in it intrudes of *Granyte;* while to the west, and extending into the Co. Tipperary, is a small exposure of *Ordovicians.* Margining the Ordovicians is *Lower Carboniferous Sandstone*, and on it *Carboniferous Limestone;* while to the northward, surmounting all, are *Coal Measures*, a part of the Leinster Coal-field.

As the anthracyte was first worked in Kilkenny by the English, the general name of "Kilkenny coal" has been given to this Irish coal; we may therefore here give a *resumé* of the history of the field.

In old times iron-ore was raised and wrought in the LEINSTER COAL-FIELD, but when, and by whom, does not appear to be now known, the first authentic records being those of the English, between 1615 and 1641. At this time Christopher Wandesford had extensive mines and works, principally in Idrone, Co. Carlow, where, besides other things, he cast and wrought ordnance. Sir Charles Coote had large workings in the Queen's Co., his furnaces and mills being at Mountrath; while in the same county Lord Londonderry had a furnace and mills at Ballynakill, and Sergeant Piggoth at Dysert.[1] All these appear to have been burnt down in 1641, but were afterwards rebuilt, and the manufacture was carried on as long as the forest lasted. It is said that after 1728 attempts had been made to smelt the iron-ore with the anthracyte, but none of them were successful.

According to Boate, coal was first discovered near Wandesford's furnace in Idrone, Co. Carlow, between 1630 and '40, while the miners were raising the clay-iron-stone. He states that the county people worked it along the edge, or basset, for their own use, but suggests that when the forests were exhausted it might come in handy. But the first pit opened was not till 1728, either in Carlow or the adjoining portion of Kilkenny. Here the coal was found to be bad, and other pits were sunk in Coolbaun Hill, near Castlecomer, where three seams were found and successfully worked. Besides these three coals, which are only found in Coolbaun Hill, others that have been found profitable to work are *the Old Colliery Three-foot Coal*, the *Rushes* or *Modubeagh Coal*, and a curious channel called the *Jarrow Coal*, which occurs in connexion with the *Old One-foot Coal.*

The Old Colliery Three-foot is practically worked out; what little that remains would scarcely pay for the getting. The One-foot Coal, which is often only five or six inches high, does not pay for working; but the Jarrow Channel, in connexion with it, has been very profitable. Unfortunately it was only of limited extent, occurring in a semicircle to the north of Coolbaun Hill, and in a nearly straight line to the south of it. Of this coal there now remains about a mile and a-half in length to the north of Coolbaun, and about two miles to the south. According to

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[1] See Dysert, King's Co., p. 286.

Mr. Dobbs' estimate it is profitable for a width of 400 yards, and is of an average height of three feet. If every cubic yard is equal to a ton of coal, we have in these portions of the channel about 2,500,000 tons of unwrought coal. There are outlying portions of this channel still unworked, which may contain something between 250,000 and 500,000 tons of coal. If the highest figure is taken, which is probably above the estimate, there will be less than 3,000,000 of tons of unwrought coal.

The only other coal available is the Mobubeagh Coal. This, under the name of Towlerton Coal, Mr. Hull estimates as profitable, about 10,000,000 tons. This estimate, however, is evidently excessive, the coal being taken as two feet high, while it rarely exceeds one foot nine inches, and in places has thined to nearly half that height. A foot coal would be valueless, as, on account of its great depth from the surface (about 216 yards below the Old Three-foot Coal), the cost of "getting" would exceed the value of the coal. Whether it is of any value cannot be known until a bore-hole is put down somewhere near the centre of the colliery. At no time was there much profitable coal in the field. It began to be mined about a century and a-half ago (1728), and now it is nearly exhausted.

The anthracite is of four classes—*stone coal; kennel*, or hard compact shaly coal; *culm*, or friable flaky coal; and *kelve*, or shaly earthy, impure coal.

Very few mineral veins have been found in the county. In the valley of the Nore was the silver mine called Argetros, which, according to the Annals, was worked A. M. 3817. In this valley silver and lead have been found at Ballygallon, near Inistioge, and Knockadrian, near Knocktopher: at the latter place, recently, they were worked for some years successfully.

KING'S COUNTY.

The majority of the rocks within the limits of this very irregular county belong to the *Carboniferous Limestone*. In these are a few exposures of *Sandstone*, and to the north of Phillipstown an intrude of *Whinstone*. At the south-east is a portion of Slieve Bloom, wherein is found an exposure of *Ordovicians* flanked by *Carboniferous Sandstones*.

As the county is for the most part enveloped in drift or bog, only a few mineral veins have been found, although it is possible more may exist, chalybeate springs being so numerous ; some of the latter, however, are evidently due to the decomposition of the pyrites in the Calp. A lead mine was for a time worked at Edenderry.

Boate mentions that prior to 1640, Sergeant-Major Pigott mined and smelted iron ore (*limonite?*) at "Dysert lands" in "the King's County," and from his account the mining works must have been extensive. At the same time Sir Adam Loftus, Viscount of Ely, had works near Mountmellick, but where he procured the ore is not stated.

The mearings of the King's and Queen's counties have been changed at different times, and portions that were in the King's County in Boate's time may now be in the Queen's : the place, Dysert Land, has not been localized, and possibly it may be the iron mines at Desert in the Queen's County (Sheets 13 and 18), now the property of Lord Carew.

Leitrim.

Nearly the whole of Leitrim is occupied by *Carboniferous* rocks, including a portion of the Connaught Coal-field. At Manorhamilton, coming in from the Co. Sligo, is a narrow exposure of Metamorphic rocks, probably of *Cambrian* age, but possibly older. At the south-east of the county is the marginal portion of a tract of *Ordovicians;* while a little exposure of similar rocks, surrounded by *Carboniferous Sandstone,* appears to the south-east, close to the Shannon.

The coals and the working of iron in the Connaught Coal-field is given in the description of the Co. Cavan, page 267. Besides the clay-iron-stone of the Coal Measures and the bog-iron-ore limonite was also mined and smelted in the seventeenth and eighteenth centuries procured from the Ordovicians at Gortinee, south-east of Drumsna near the Shannon. In late years, between 1860 and 1880, some ore was also raised here, and exported to England.

In the Metamorphic Cambrians (?) at Gortnaskeagh, Pollboy,

and Shanvans, N. W. of Manorhamilton, copper was mined prior to 184,5 while lead was raised in the adjoining mine of Twigspark. The lodes at Pollboy and Shanvans, although in the Metamorphic rocks appear to have been of Carboniferous or of part Carboniferous age ; as associated with the ores, " copper with a little lead," there was Dolomyte. From the position of the lodes it may be suggested that they are " contact lodes," at the junction of the Carboniferous and the Metamorphic rocks, they belonging to the same class of lodes as the great lode at Silvermines, Co. Tipperary. Along the line of contact there ought to be other deposits not yet discovered.

The old attals and shafts prove early mining operations ; but the date at which the lode wsa first worked seems to be now unknown.

LIMERICK.

To the south-east, coming in from the Co. Tipperary (a part of Slieve Phelim) are *Ordovician* rocks, capped by *Carboniferous Sandstones* (Upper Old Red) ; while the rest of the area is occupied by limestone or other *Carboniferous* rocks. To the west there are *Coal Measures*, a part of the WEST MUNSTER COAL-FIELD ; while between these hills and those of Slieve Phelim the plain is principally occupied by the *Carboniferous Limestone*, but having associated with it beds and intrudes of *Volcanic* rocks and a few outlying *Sandstone* exposures.

At Ballybrood there is a small patch of *Coal Measure* surrounded by *Volcanic* rocks ; the latter possibly represent the ruined walls of a Carboniferous Volcano.

As has been mentioned in the description of the Co. Cork, the coals in the Co. Limerick are thin : formerly they were worked at or near their outcrop ; but no deep trials has been satisfactory, the coals proved, not to be sufficient in quantity or quality to pay for deep workings. Iron ore, in the seventeenth and early part of the eighteenth centuries seems to have been extensively worked, especially in the vicinity of the Shannon ; partly to supply the furnaces near Glin and Loughill, and in part to be sent by boat up the Shannon for the use of the furnaces and mills in the vicinity of Lough Derg.

In the Co. Limerick, more than elsewhere in Ireland, the

Carboniferous Limestone is divided into Lower Shaly Limestone Fenistella Limestone, and Calp; the latter in part of the Burren type. Above and below the Fenestella Limestone are well-marked cherty zones, and below both of these, especially the first, mineral accumulations occur. Some rich pockets and shoots were found and worked out prior to 1850; while since then lead has been found in a few places, but the extent of the deposits have not been proved. According to Lewis (1837), "there are indications of a valuable mineral ore near Tory Hill;" no trials, however, seem to have been made thereabouts.

In the Carboniferous Sandstone and the Ordovicians a few small veins with copper have been found, but not sufficient to make mines.

Large amethysts and cairngorms are found near Shanid Castle and Foynes.

Londonderry.

At the east of the county, extending in from the Co. Antrim, there is a tract of *Eocene* (?) *Doleryte*, which overlies the *Cretaceous*, *Jurassic*, *Triassic*, and *Carboniferous* rocks. To the northward the rocks of these older formations, except the Carboniferous, form more or less narrow, continuous, successive strips, margining the Doleryte; but southward the latter more or less overlaps them all. The Carboniferous rocks are for the most part of the North of Ireland "Calp type;" but in places there are good limestones, and in others sandstones and conglomerates of the *Lower Carboniferous types*. The Carboniferous rocks were evidently accumulated in valleys in the older Metamorphic rocks, which occupy the rest of the area, and therefrom into the counties of Donegal and Tyrone. They are probably of Ordovician age. With the Metamorphic rocks are associated intrudes of Granyte.

In the Eocene (?) Diorytes, as in the Co. Antrim, there are beds of iron-ore; but not as numerous or valuable. In the Calp shales near Draperstown are clay-iron-stone bands and nodules: worked by Rennie, and smelted in the valley of the Moyola, prior to 1640. This Iron Master also mined hematite and limonite in the Ordovician and Granyte rocks. Between 1860 and 1870 openings were made on these lodes, but no permanent work done,

on account of the depression in the iron trade. In the Ordovician rocks the iron in general, is associated with manganese.

Traces of copper and sulphur ores have been found in the rocks (*Ordovicians*) of the Ballynascreen mountains, but none of the veins have been opened up.

Prior to 1641 Boate records gold as occurring in the gravels of the Moyola river, but since then none seems to have been found.

There is a possibility that Coal Measures, with profitable coals may yet be found under the Trias at the south-east of the county.—See *Ulster Coal-field*, Co. Tyrone, p. 298.

Portlock calls attention to large beds of ochre at Aughlish and Tamnagh, in the parish of Banagher, and Glenviggan in the parish of Ballinascreen, as suitable for making red paint, similar to that employed in Sweden to paint and preserve the wooden houses. The surface deposits, or bog-iron-ore, is in places at present exported, to be used in the purification of gas.

LONGFORD.

In the north-east of the county, coming in from the Co. Cavan, is the margin of a tract of *Ordovician* rocks. The rest of the area is principally *Carboniferous Limestones*, with, to the north, a margin of *Carboniferous Sandstones* and *Shales*. In a few places are small protrudes of *Ordovicians*, associated with *Carboniferous Sandstones*.

The localities for minerals are few (*see Lists*); the most important are the iron lodes at Cleenragh and Enaghan, near Lough Gowna. These were worked in the seventeenth century, and also prior to 1870, by Dr. Ritchie of Belfast. In the earlier times they seem to have been smelted in the county, but Ritchie exported them, carrying them across the lake in boats, and thence by rail to the port. Silver-lead is recorded as occurring in the Carboniferous Limestones at Longford.

LOUTH.

The major portion of this area is occupied by *Ordovician* rocks, on which, to the south, west, north, and north-east, are small tracts of *Carboniferous Limestones, with its Sandstones and Shales.*

To the north-east, forming a hilly country south-west of Carlingford Lough, are peculiar *Granitic and other Intrusive rocks.*

In different places in the Ordovicians, veins of lead and copper have been found, and at Jonesborough antimony; while mines were worked about the year 1840 at Salterstown, and near Clogher At the junctions of the Granyte and the Ordovicians traces of lead. occur in different places.

Near Clogher Head there is a poor iron-ore, and in different places in the hills are the ruins of old iron works: the ore for the latter may have been imported.

Mayo.

In this county about half the area is occupied by Metamorphic rocks (probably *Ordovicians* and *Cambrians*) and their associated *Granytes.* Some of the Metamorphic rocks are said to be Laurentians, but lithologically, and apparently petrologically, the younger rocks of the series are similar to the Co. Galway rocks that carry fossils of Llandeilo types. On them, to the south-west, and extending into the Co. Galway, are *Silurians;* while smaller tracts of the same age occur south, west, north, and north-east of Clew Bay, the last in Croagh Moyle, being the largest. The rest of the area is occupied by Carboniferous rocks, *Coal Measures*, &c.

A valueless coal occurs in the Coal Measure, but associated, with it is clay-iron-stone, that was worked to be smelted in Gildeas' furnace at Port Royal.

Limonite, or hematite, was mined in Cross and Tallaghan, barony of Erris, and in the Cloonaghan and Deel river valleys, barony of Tirawley. Formerly Sir George Shaen smelted and milled iron near the Mullet; while a little later Rutledge had works on the Deel. Both these Iron Masters had to discontinue their works for want of fuel when the woods were exhausted.

At Port Royal, near Ballinrobe, the Gildeas, in Charles II.'s time, were given a grant of land, in which they mined and smelted iron. The ore principally used was bog-iron-ore, mixed with the clay-iron-stone raised near Balla, some miles to the north; while tradition has it that they also procured limonite

from the neighbouring Silurian and Ordovician hills. The furnace at Port Royal is supposed to have been put out at the end of the eighteenth century, being one of the last wood charcoal furnaces alight.

Very few other mineral veins are recorded, those named being ores of copper, sulphur, and lead. A silver-lead mine was formerly worked at Sheefry, between Westport and Killary Bay; while trials were made on coppery lodes in Corraun Achill. On account of the great area of the county, and the favourable nature of the rocks, in places, it would appear possible, if proper search was made, that some profitable lodes might be found. Lewis states "rich deposits of manganese have been found in the neighbourhood of Westport."

MEATH.

To the south-east of this county, near Balbriggan, also north of the valley of the Boyne, there are tracts of *Ordovicians*; while the rest of the area is nearly solely occupied by *Carboniferous Limestones*, principally of the "Calp type." On it, in places, are small patches of *Coal Measure Shales;* while to the north, coming in from the county Monaghan, is the south end of a small tract of *Trias*, associated with a patch of *Coal Measures.*

In the Trias there is gypsum, formerly mined (*Monaghan*, page 252); and in the adjoining Coal Measures there is a thin coal, that was worked a little, along its outcrop. Although profitable copper lodes are not usually found in the Irish Carboniferous Limestone, yet about 1800 copper-ore was raised at three places near Walterstown; and subsequently at Beaupark, near Slane. Also in the Carboniferous Limestone, lead was worked at Athboy; while in the Ordovicians at Clogher, near Ardcath, there is a lead mine, considered by Griffith to be very ancient. Lewis reports a "rich copper lode," near the banks of the Boyne, "unworkable profitably on account of the influx of water."

Monaghan.

Both to the north and south are tracts of *Carboniferous* rocks; while on the latter is a small outlyer of *Trias*, margined eastward by *Coal Measures*. Nearly all the rest of the area is occupied by *Ordovicians*.

In the Trias to the S.W. of Carrickmacross there is a considerable deposit of gypsum, some time since mined and manufactured into "Plaster of Paris" at Knocknacran, until the works were burned down about the year 1869. In the Coal Measure is a valueless coal, while other valueless coals occur to the north of the county, near Slievebeagh. The tumblers of limonite found S.E. of Kingscourt are mentioned in the "Iron List," Part I.

Veins of lead-ore have been found in numerous places, those at Lisglassan and Tullybuck being associated with antimony; while in other places there was barytes, or a little zinc. Lewis states that in the "Creina Hills" there had been works for reducing lead; but they were abandoned some years prior to 1838.

The majority of the mines recorded in this county seem to have been worked between 1830 and 1855, but some before these dates. The lodes in this county appear in general to have been small; but, on account of their number, also that others occur in the neighbouring counties of Cavan, Armagh, and Louth, it would appear that mining might be remunerative when trade revives; especially if reducing works, calculated to utilize all the mineral products were erected at a good centre.

Queen's County.

Slieve Bloom, which lies to the north-west of the county, has a nucleus of *Ordovicians*, the slopes of these hills being *Carboniferous Sandstones and Shales*. The rest of the area is occupied by *Carboniferous Limestones* and *Coal Measures*, the latter being a portion of the Leinster Coal-field.

The iron ore and coals have already been described with those of the Co. Kilkenny (page 283). In this county coal was first

discovered at Gale and Cullenagh Hills while working the iron-ores. The "Gale Hill coal" is interesting, as one of the first discovered; but is also important because a little below it, is the great horizon where the iron-ore was worked in the seventeenth century. For no apparent reason, except it may be to introduce a new set of names for the coals, this coal has been ignored in the second "Geological Survey Memoir," published in 1881 (*Parts of sheets*, 127, 128, 136, 137, &c., *by Messrs. Hull and Hardman*); although the same coal, under a new name, is recognized in other places. After Wandesford, in 1728, commenced to mine in the Co. Kilkenny, the Grand Canal Company and others put down a number of bore-holes in this county, thereby proving the extension of the Kilkenny coals. These coals, however, are now nearly worked out (page 285).

The iron mining, smelting, and working (*List of Iron Masters*, page 259) were considerable, both before and after 1641, and only ceased when the forests were exhausted. At Dysert, near Maryborough, the property of Lord Carew, are limonite veins, formerly extensively worked; there, as previously suggested (page 286), may be the mines mentioned by Boate as situated in the King's Co., and worked by Sergeant Pigott.

Traces of copper and lead have been found in the Ordovicians of Slieve Bloom, but the localities are not recorded.

ROSCOMMON.

In the Curlew Mountains, at the north of the county, are reddish and greenish *Silurians*, with their associated felspathic Exotic rocks, the Silurians being margined by *Lower Carboniferous Sandstones and Shales.* To the east, near the Shannon, in Slieve Baun, are small exposures of *Ordovicians*, also margined by similar rocks; while the latter also form small tracts to the W.S.W. of Roscommon, and the N.E. of Castlereagh. Most of the rest of the area is occupied by *Carboniferous Limestones*, they having on them at Lough Allen—*Coal Measures*—a portion of the CONNAUGHT COAL-FIELD.

The coals and clay-iron-stone appear in the description of the Co. Cavan (page 267). No other metallic ores are recorded. In

places, however, there appear to be indications of lodes, but the great head of drift, or bog, prevents them from being easily found.

Sligo.

The *Carboniferous Limestones* occupy the principal portion of this area, having on them to the south-east a small but rich tract of *Coal Measures*, part of the Connaught Coal-field. Crossing the county obliquely is the Ox Mountain range, the rocks being metamorphic, flanked in places by *Lower Carboniferous Sandstone:* these Metamorphic rocks are probably of *Cambrian* and *Ordovician* ages, although, from their lithological characters solely, they are stated by Professor Hull to be Laurentians; but the petrological evidence seems to be conclusive against such an age. At the south margin of the county are small exposures of the Curlew Mountain Silurians.

The coals and clay-iron-stone of the Connaught Coal-field are mentioned in the history of the Co. Cavan. Other iron-ores, however, seem to have been raised, and were smelted at Ballintogher "and at the base of the Ox Mountains." Lewis also states, when writing in 1837, that "near Screevenamuck are excavations, where the ore was raised as long as timber could be procured for smelting it, the last furnace having been put out in 1768." At Ballynakill, between Ballintogher and Riverstown, are the ruins of extensive iron works; while limonite appears to have been mined in the adjoining Carboniferous Limestone.

Lead has been worked in the Metamorphic rocks, and silver-lead in the Carboniferous Limestones near Ballysodare; while lead, copper, and barytes have been found and worked in the King's Mountain. The Abbeytown mine, near Ballysodare, has been worked on and off during the last hundred years. In Glencarberry, King's Mountain, unsuccessful attempts to work profitably the large accumulation of barytes were made between 1870 and 1880.

Well-coloured and well-shaped large amethysts have been procured in the neighbourhood of Ballymote.

TIPPERARY.

The Killenaule, or EAST MUNSTER COAL-FIELD, lies to the east of this county, it being joined to the Kilkenny field by a tract of *Lower Coal Measures*—while outlying small patches of the latter are found N. E. and S. W. of Fethard, N. W. of Clonmel, at the Rock of Cashel, and in Slievenamuck, S. W. of Tipperary. To the S. E. of the area in Slievenaman are *Ordovicians*, flanked by *Lower Carboniferous Sandstone;* to the S. W., in Knockmealdon, are rocks that possibly may be the eastern extension of the Co. Cork, *Devonian* and *Silurians;* to the west, in the Galtees and Slievenamuck, are small exposures of *Ordovicians*, margined by *Lower Carboniferous Sandstone;* and to the N. W., in the Arra Mountains, and Slieve Phelim, are similar groups of rocks, similarly related; while most of the low country is occupied by the *Carboniferous Limestones.*

Between 1730 and 1740, coal was searched for and found by the Langleys in the Coalbrook Colliery, but some forty or fifty years seem to have elapsed before it was worked by the Goings in Earl's Hill; and elsewhere by the Mining Company of Ireland—the collieries not being well developed till after 1825.

The profitable coals were—*Surface*, *Parkenaclea*, *Clashacona*, *Main*, and *Glengoola*. All the beds above the Main coal were solely found in Earl's Hill, where the measures are thickest, while the Main coal, besides here, was only found in some detached basins. All the profitable portions of these coals, except the Glengoola beds, and small tracts of limited extent of others, seem now to be worked out.

Associated with the Glengoola coal in Coalbrook and elsewhere are some seams of rich clay-iron-stone, but I can find no records of these having been mined or smelted. Other iron ore, however, was raised in the older rocks, and smelted at Gortnahalla, in the valley of the Clodiagh, to the S. W. of Borrisoleagh. Some ore is also said to have been raised and smelted near Roscrea: these latter works may, however, have been in the King's County.

At Gleninchinaveigh, near Upper Cross, there is a vein containing anthracite and graphite, four feet wide at surface. This, in 1857, was sunk on for a depth of ten fathoms, but the walls

closed in and cut it out; it was also driven on for five or six fathoms.

Lead, copper, and other minerals, as given in the Lists, Part I., have been found and worked in different places; there having been prehistoric workings on the silver-lead at Garrane, near Toomavara; at Silvermines, near Nenagh; and at Garrykennedy, on Lough Derg.

Of the mines, the most important and interesting are those on the great Mineral Channel at Silvermines. Boate states, in rather disparaging terms, that this mine was first discovered by the English about the year 1600; but the researches made during the present century, and the statements in the Annals, would suggest it had previously been worked by the ancient Irish, as were also the mines to the westward, at Garrykennedy; and to the eastward, at Garrane.

From Boate we learn that at first, Silvermine was supposed to be a lead mine, but afterwards they found it contained "three pounds of silver to the ton of lead;" also "some quicksilver." As far as I can learn no trace of the latter has been detected in late years. Under the King the mine was farmed by Sir William Russel, Sir Basil Brook, and Sir George Hamilton; but the mine was destroyed, and the works burnt down in 1641, by Hugh O'Kennedy, brother to John Mac Dermott O'Kennedy, who ought to have been its legitimate owner. After the troubled times the English company seem to have again worked it till their lease expired, about 1730: subsequent to this it was worked by different companies, who found and opened up new lodes, till eventually it came into the hands of a Mr. Hudson, who at the beginning of the present century sold his interest to the General Mining Company of Ireland; these carried on active operations till about 1870.

After the time of the English company various lodes were discovered in the county to the westward; some of them containing argentiferous copper and lead, others argentiferous lead—the latter giving eighty ounces of silver to the ton. In 1858, Captain Thomas King, while exploring the ancient lead and silver mines, discovered electric calimine; it evidently being due to the chemical decomposition of the blende that had been run as attals or wastes into the ancient levels; this for some time was profitably worked.

The Silvermines Mineral Channel is interesting, being a "con-

tact lode" at the junction of the Carboniferous and Ordovician rocks, extending for at least thirty miles; from Gallow's Hill, Co. Clare, to the westward; to Toomavara on the eastward. Along this line mines have been worked at Garran, near Toomavara, and at Silvermines; while indications have been detected in the Co. Clare, which seem to suggest that in other places along this "contact break" profitable lodes may yet be discovered.

At Lackamore, copper was raised in old times, while an unsuccessful attempt to work the lodes was made between 1800 and 1810; they were subsequently opened on by the Mining Company, who broke some very rich ore; but as the quantity was small, they also abandoned them. The last adventurers were the Messrs. Taylors of London, who raised some ore up to 1859. Lewis mentions a lode found in the townlands of Cappaghwhite, Ballysinode, and Gortdrum, which contains rich copper in bunches, and was leased to the Mining Company, who, in 1826, spent some money at Gortdrum, but apparently without any return.

At Hollyford there are two parallel lodes cut off by a cross course. On the eastern, or Ballycolein lode, there was an ancient mine; as about 1850, at the cross course, were found "Old Mens" workings and tools. In 1858 the western lode was worked under Captain John Pascoe, while subsequently the mines got into the hands of an English bogus company, who became bankrupts.

TYRONE.

The geology of Tyrone is very interesting. To the north, coming in from Londonderry and Donegal, are Metamorphic rocks, which belong to two distinct geological periods, probably *Ordovicians* and *Cambrians*—south of the latter, at Pomeroy, are unaltered *Ordovicians*. Dr. Hincks has suggested that the older rocks may be Laurentians, but solely on account of their lithological characters; they are evidently of the same age as the older rocks in Donegal. The Pomeroy Ordovicians are overlaid by *Silurians* of the Fermanagh type, and those to the south and east by *Carboniferous Sandstones*, *Shales*, and *Limestones;* and on the latter, to the north-eastward of Dungannon, are the *Coal Measures* of the ULSTER COAL-FIELDS. Margining, and on the Coal Measure,

are *Trias rocks;* and in places *Cretaceous rocks* (White Limestone), *Eocene* (?) Doleryte, and the "Lough Neagh beds"—the age of the last being still disputed.

Associated with the Metamorphic rocks are *Granitic rocks* of three or more distinct ages. In the westward and north-westward there are other tracts of Carboniferous rocks.

In the south of the county the Carboniferous rocks have well marked divisions, having a central zone of sandstones and shales (*Calp*), while to the westward and north-westward they are more mixed up. The Calp of Ulster is more or less similar to the Coal Measure sandstones and shales, having in it, in the Co. Derry, workable beds of clay-iron-stone; and at Ballycastle, Co. Antrim, workable coals. By some observers the rocks of these two distinct groups have been confounded together. This is a matter of importance, as this incorrect mapping has led persons to make unsuccessful trials for coal in the Calp.

In the Silurian are the characteristic felspathic bedded rocks (*eurytes*); while associated with the Trias, in the north of the county, are dolomytes, said to contain fossils of *Permian types*.

In the "Lough Neagh beds" are seams of lignite, but too insignificant to be valuable; silicious pieces of the lignite are known as "Lough Neagh hones."

In the Trias at Croagh, also elsewhere, gypsum has been found, but not in sufficient quantity to be economically worked.

The Tyrone coals are seemingly of great importance. As has already been mentioned, the coals in Leinster and Munster are in the *Upper Measures*, and those in the Connaught field in the *Middle Measures;* but in Tyrone they are found both in the *Middle and Upper Measures.* Furthermore, the Ulster are gas coals, while those of Leinster and Munster are anthracates; those of the Connaught field seem to be intermediate between both. The extent of the coal-field is unknown; for although the coal at the margins of the exposed field must extend under the adjoining younger rocks, this extension has never been proved by either borings or sinkings.

The coals at Drumglass, near Dungannon, in the *Middle Measures*, have had their exact height above the Limestone proved by a series of bore-holes; but their extent is unknown, as it is still an open question whether they extend under the whole or only a part of the field.

The coals of the *Upper Measures* in Annagher, Coalisland, and Annaghone have respectively individual characteristics. It has been supposed that those of the Annagher series are above the Coalisland series, but there are no positive proofs that this is the case, while the facts appear to be against such a supposition. The *Baltiboy* coal of the Coalisland series is said to be the sixth or lowest coal of the Annagher series. This, according to the published section, is, at the most, only 192 feet above the *Derry* or highest workable coal in the Coalisland series; while in the intervening measures there are four thin coals, ranging from nine inches to two feet in thickness; but in the bore-hole put down by Griffith for a depth of 270 feet below the sixth coal at Annagher no coal was found. It is possible that these four minor coals might have died out, and be unrepresented in the measures under Annagher; but it is scarcely possible that the *Derry Coal*, from three to five feet thick, should be totally absent. In the Annaghone Colliery, the *Main Coal* is said to be "undoubtedly" the Annagher *Nine-foot Coal*, which would necessitate a down throw to the eastward of over 2000 feet. It seems to me therefore more likely that the different series of coals in the several portions of the Upper Measures, are in more or less detached basins, in each of which the strata were accumulated under different conditions, similarly as in Kilkenny and Tipperary.

We, however, do know, that in the *Annagher series* there are four coals, over 2·5 feet thick, more or less capable of being profitably worked; while in the *Coalisland series* there are three coals, over three feet high. The *Annaghone* colliery had a coal nine feet thick, and above it another that varies from 1·5 to 3 feet. There are no apparent reasons why these Annaghone coals may not extend northward and north-eastward under the Trias, even into the Co. Londonderry.

From the very imperfect data at present procurable there is no possibility of making any sort of an approximate estimate of the quantity of unwrought profitable coal in this portion of Ulster; but it appears safe to suggest that there is probably much more unwrought coal here, than elsewhere in Ireland.

The coals are bituminous, and when burnt have a white ash; near the surface they are brittle, but improve in depth. They were not wrought, at least extensively, until the present century,

when they were systematically looked for by Griffith and the Hibernian Mining Company.

In places in the Coal Measures good clay-iron-stone is found; but I cannot find any records of its having been raised or smelted in old or modern times. Elsewhere, however, in the Carboniferous Limestone and the Ordovicians, hematite and limonite were raised for smelting in the seventeenth and eighteenth centuries, and more recently for exportation (*see* Londonderry, page 288), the localities being given in the List, Part I.[1]

Antimony has been found in the Munterlong Mountains, and lead in Crockanboy and Trebane West, all near Gortin; but none of the minerals appear to have been worked. In the Silurians at Crannogue, near Pomeroy, a little copper was raised; while elsewhere in these rocks, both in this county and also in Fermanagh, there are traces and indications of this mineral, which would suggest that, if properly searched for, a paying lode might be found.

Waterford.

In the west of the county of Waterford is the eastern termination of the rocks of the *Cork types*, they gradually, eastward and northward, changing into the ordinary *Central Ireland types*.

To the eastward, coming in from the Co. Wexford, are *Ordovicians*, with their associated, more or less interbedded, igneous rocks; and over these, to the northward, are *Lower Carboniferous Sandstones*, *Shales*, and *Limestones*. But to the westward, in the Commeragh Mountains, on these Ordovicians are, more or less, conglomeritic and argillaceous rocks; and these possibly are the representatives of the littoral accumulation of the Cork *Devonian* or even *Silurian;* this, however, has still to be proved. To the S.E., at the Bonmahon mines are a few patches of similar conglomerates, which for the reason stated hereafter (*Wexford*, p. 302) are supposed to be *Silurians*. *Devonian* (or *Silurian*) seem also to occur further south, in the long hill, or "drum," between the two Decies.

[1] Clay-iron-stone is recorded by Boate as having being worked in the Calp (?) shales, in "Nether Tyrone, by the side of the rivulet Lishan." "Nether Tyrone" is the present Co. Londonderry.

On the Devonians (?), lying in nearly east and west troughs, are *Lower Carboniferous Sandstone, Shales, and Limestones.*

In the Devonian rocks of the Coshs and the Decies baronies, that is, south of the valley from Lismore to Dungarvan; iron ore was extensively raised for smelting in the seventeenth and eighteenth centuries; Lord Cork having large works at Saltersbridge, while Sir Walter Raleigh's principal mines were at Dromslig; but the ores from Minehead and Ardmore were specially prized, as they could be converted into the finest steel. Here, as elsewhere, the furnaces were probably in the vicinity of the mines. When Smith wrote in 1750, Lord Cork's furnace only appears to have been alight, and it was put out shortly afterwards. In Dromslig and the neighbouring townlands iron ore, for exportation, was raised between 1850 and 1860, and even a little later.

Very valuable lodes, both of lead and copper, were formerly worked in different places in the *Second*, or *Ballymoney Series* of the Ordovicians. Lewis mentions a valuable silver-lead lode that was worked at the Hill of Cruagh, parish of Riesk (*Sheet* 17); and another of lead in the River Mahon Valley, near Mountain Castle (*Sheet* 15); also silver-lead that was dug out of the sands of Kilmurrin beach. These three localities seem to have escaped Griffith's notice, as they do not appear to be mentioned by him. Nothing is now known of the copper and silver-lead lodes worked near Ardmore; but, from the specimens found in the waste heaps, they are supposed to have been rich.

In this county the best known mines are the "Bonmahon Coppers," so called as the major portion of the ore was copper, although in the setts some valuable silver-lead veins were also found and worked. At Knockmahon, mines were worked in the old days, as in the "Stage Lode" "Old Men's workings," with wooden and stone implements, were found. Subsequently, from Queen Elizabeth's time, down to 1730, some of the lodes, at intervals, appear to have been worked, while at the latter date they were in the hands of a Mr. Hume, who for some years worked the Stage Lode very successfully. Next we hear of Colonel Hall, and Mr. Galway, who spent a large sum unsuccessfully, and they, in 1796, passed their interests to the Hibernia Mining Company. These also do not seem to have been successful, as they sold the property, in 1824, to the Mining Company of Ireland. The latter

from that date, until about 1876, carried on the mining with varying success; while about 1880 the works were totally dismantled. The last adventurers seem to have been more extensive in their operations than any of their predecessors, as they held five royalties —Tankardstown, Knockmahon, Kilduane, Ballinasisla, and Bonmahon. Their first mine was on the "Trawna Stella" lode, in the west portion of Bonmahon; hence the name by which all the mines were afterwards known.

The future of these mines is very obscure, as from appearances there seems to be no hope for them; but it must be remembered that although adventurer after adventurer gave them up as valueless, yet the Mining Company found riches—the nett profits of the mines in 1862 alone exceeding £20,000. (*See Du Noyer, Ex. Sheet* 168, *Geol. Map, p.* 81).

Westmeath.

This area is occupied by *Carboniferous Limestones*, except a small exposure of *Lower Carboniferous Sandstone* near Moate, a second west of Kilbeggan, and a minute tract of *Ordovicians*, margined by *Carboniferous Lower Sandstone*, to the north of Killucan.

This county is absent from Griffith's lists, there being no recent mines in it. Small bits of lead and copper have been picked up in places; while coaly seams and clay-iron-stones have been found in the Calp shales. There is no prospect of profitable coal ever being found; but copper and lead veins, especially the last, ought to exist, but are hard to discover on account of the envelope of drift and bog.

In places there are the traces of old iron works, while it is possible that some of the Calp iron ores were utilized.

Wexford.

Two-thirds of this county are *Ordovicians*, in part metamorphosed. These are fringed along their N.W. margin by *Granyte*, part of the great intrude of the Leinster range. S. E. of the Ordovicians, and coming up from under them, are *Cambrians*.

The latter are also, in part, metamorphosed; those at Carnsore, to the south-east, being changed into *Granitic rocks.* Patches of these rocks, for no apparent reason, except lithological characters, are said to be of *Laurentian* age. Crossing the Cambrian, and on the Ordovician, in Hook Promontory, are *Carboniferous Limestones, Shales, and Sandstones.*

To the south-east, on the Cambrians, adjoining Ballygeary Bay, is a small outlying tract of Ordovicians. Formerly on the coast, to the S. E. of the new pier, the basal bed, a fine conglomerate, identical in aspect with the silurian conglomerate at Bonmahon, Co. Waterford (page 301), could be seen, but now it is covered up by a sand accumulation.

The Ordovicians of S. E. Ireland are separated into three well-marked groups, which are traceable more or less distinctly in the rest of Ireland. These groups may be called, Lower—*Black Shale Series;* Middle—*Volcanic,* or *Ballymoney Series;* Upper—*Slate,* or *Slieve-Phelim Series.*

The known mineral veins are few, which may in part be due to the deep drift. A few veins of lead and copper, but not of much account, have been worked in the Ordovicians since the beginning of the century; while near Bannow Bay are attals, or old waste heaps, said to be the *debris* from mines worked by the Ostmen.

In this neighbourhood, at the Castles of Clonmines, there is said to have been a mint in the time of Charles II., the coins having been made from silver procured in the vicinity. Some lead and barytes are found in the Carboniferous rocks, and in one place concretions of native sulphur.

Prior to the stoppage of Chamney's iron works at Shillelagh, Co. Wicklow (Wicklow, p. 246), these Iron Masters smelted iron largely in bloomeries in the north-west portion of the county, and probably also raised ore, as traces of what seem to have been old workings have been observed near Galbally and elsewhere. There are also in different places, associated with the rocks of the *Ballymoney Series,* not only in this county, but also to the N. E., in the Co. Wicklow, and S. W. in the Co. Waterford "Black Heaps." These are of greater or less size, and consist of roasted shingle and black stuff, with, in some of them, what seems to have been a hearth. Some of the smaller ones are said to have been the places

where they "roasted the wild deer"[1] in former times; but others evidently appear to have been bloomeries, or for some such metalurgical process. The roasted shingle is principally broken-up fragments of the Ferriferous Felstones.

To the north of Gorey, at Ballynastraw, also elsewhere in the purple shales and slate of the lower portion of the *Slate Series*, are lentils, or irregularly-bedded masses of earthy limonite; while in places along the Ballymoney cliffs are beds, of a low percentage, of calybite. There are no records of these ores having been worked.

In the Ordovicians, anthracite, and in places plumbago, is recorded. At the north-east mearing of the county; in two places in the Ballymoney cliffs, where they have fire-clays and carbonaceous shales associated; at Greenfield, near Enniscorthy; near Wilton; in Doonoony; and near Castle Talbot; while it is reported to have been found in two places in the barony of Forth. From trials made the veins seem to be only from one to four inches wide, and of no value. Some of the best of the carbonaceous shales, if there were mines in the neighbourhood, might possibly be worked advantageously as a bye-product.

Some good specimens of asbestos are said to have been found at Bloomfield, near Enniscorthy.

Wicklow.

To the north-east, adjoining the sea, are *Cambrians;* the rest of the county rocks are *Ordovicians*, associated with a wide intrude of *Granyte*, part of the Leinster Granyte range. There are also small detached outbursts of Granyte, while the Cambrians and Ordovicians are in part metamorphosed.

The Granytes belong to different Geological Periods. The main mass is Post-Ordovician, but with it, to the southward, in the parish of Shillelagh, and extending into Kildare and Carlow, is a considerable tract of a very coarsely crystalline rock, which might be called *Pegmatyte* (locally called *Bastard Granyte*). This evidently is newer than the normal "Leinster Granyte" of Haughton. In the older Granytes, also in detached intrudes, are

[1] Called *Fellaght feca* in the Co. Waterford.

the newer Granytes, which are possibly of Silurian or Devonian age. These younger Granytes, for reasons hereafter given, may possibly have some sort of connexion with the great Mineral Channel of the Co. Wicklow.

Wicklow is the premier county in Ireland for mines, not on account of the ores being very rich, but in consequence of the great extent of the mineral ground, and that the mining operations have been in varying activity at intervals from time immemorial.

The great Mineral Channel extends from near the sea, southward of Wicklow, nearly continuously, in a south-west direction, to Ovoca, and from that to the flanks of Croghan-Kinshella, a distance of about fifteen miles. In the Channel, and adjoining it, the rocks are "iron masked," similar to the rocks adjoining the intrude of the younger Granyte; this has led me to suggest that this Channel has a possible connexion with the vulcanicity to which the younger Granytes are an adjunct. In places along the Channel there were very ancient mining operations.

At Connary and Cronebane, in the EAST OVOCA MINES, there was ancient mining for lead and silver, as has been proved in recent years by the finding of "Old Mens' workings," stones—hammers, and other primitive implements. Further south-west, at Moneyteigue, there were other early workings, apparently for iron. Tradition has it, that iron was raised here by the early Irish, and that after the O'Helys were driven out of the country, the Norman knights, Raymond and Sillery, built castles in the vicinity, and worked an iron trade. Towards the end of Elizabeth's reign, the Earl of Stafford (Black Tom), took possession of the county. He, and afterwards his successor, mined and worked iron, through their tenants, or Iron-Masters, the Paynes, the Bacons, and the Chamneys.

The works belonging to the earlier *protegés* of this dynasty cannot be specially mentioned; but between Aughrim and Ballynaclash there are the ruins of very ancient iron works and mines, that are supposed to have belonged to them; as are also others on borders of this county and Kildare.

Bacon, an Englishman, came over and built works at Shillelagh. Before his time most of the charcoal was sent to Wales to be there used in the final working of the iron. He, however, considered it would be more economical to import the pig-iron than

export the charcoal. This adventure was most successful, and at the time of the Commission for examining into the state of the Timber in Ireland, he had amassed a sum of over one million pounds. Having only one child, a daughter, the bait was too seductive to one of the Commissioners, a scion of the twice noble house of Cholmondelay, who became Bacon's son-in-law and successor; relinquishing his heritage, and changing his name to Chamney.[1]

The Chamneys greatly increased the trade; having works not only at Shillelagh, where Bacon established the industry, but also in the Vale of Clara; at Bally na clash, or "Clash," in Glanmalure; at Garrynagowlaun (Woodenbridge) and Aughrim, in the Vale of the Darragh Water; and elsewhere; besides innumerable bloomeries; his works, popularly, being said to have "filled the country." In an old document there are records of some fifty-two or more distinct works in Wicklow, Wexford, and Carlow. The "Clash" and Shillelagh iron was of a very superior quality, and at the present day any old chains or other articles made of it are highly prized by the smith.[2]

Bacon may have only manufactured imported pig-iron; but the Chamneys also smelted the native ores of Ballycapple, north-east of Redcross; and Knock na mohill mines, westward of Ovoca. Elsewhere in Ireland the Iron trade gradually ceased, as the woods were exhausted; but here it seems to have come to a sudden and untimely end prior to 1761, on account of a fracas between Chamney and the English agent of the lord of the soil.[3]

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[1] Although he changed his name during his life, and his descendants adopted the change, yet on his tomb in Carnew Churchyard, his real name and lineage are given.

[2] A smith who had a forge near Castle McAdam, is popularly reported to have gone night after night to abstract the "Clash iron" staples and bolts out of the granyte gate posts, so common in the county. Whether he did it or not, the staples now, as a general rule, have all disappeared. I have known a pound of "Clash iron" being exchanged for three pounds of the ordinary iron at present in use.

[3] Written information about the old iron works is very hard to procure, as nearly all the Chamney Papers appeared to have been destroyed when the family were dispersed. Old people will tell you that "the noise of the Chamney hammer" was a weather guide, and show you bits of the Clash or Shillalagh iron ore pots; but no one seems capable of giving special information in respect to any of the old works; all say, "I supposed they belonged to Chamney, as they say he had works everywhere." Also they know that the ore and his iron were carried in baskets on horseback from Wicklow port and from the different mines; and the old horse tracks from the mines and Wicklow to the furnace can still be shown. That the trail from Wicklow to Shillelagh must have been a very ancient one, is suggested by its passing the sites of Sillerey's and Raymond's Castles.

The principal ore in the veins of the Mineral Channel is sulphur-ore (*Pyrites*). This in general has a "back," or "gossan," of iron ore, or ochre; while in places between the gossan and the real lode there is a "gossan lode" principally of lead. There are, however, local peculiarities hereafter to be mentioned. Some of the sulphur-ore is coppery, having from two to four units of copper, while in newer lodes there was a mixed ore, in part pyrite, and in part chalcopyrite, that gave from six to ten units of copper. As these mines, at the beginning of the century, were worked solely for the copper in the ores they are generally known as "copper mines," a title to which they are not entitled.

The earliest workings of which we can detect traces were for lead, in East Cronebane, and for iron in Moneyteigue, after which history is more or less a blank till we come to near the end of the last century; for although we know iron was extensively raised, probably in the seventeenth and eighteenth centuries, at Knoch na mohill, Ballycapple, and other ores elsewhere; yet we cannot tell exactly at what time or by whom the mines were worked.[1]

At the end of the last century the Ovoca mines were in the hands of an English syndicate, who worked them for lead and copper. But early in the present century, the Channel immediately east and west of the Ovoca river seems to have been broken up into five mining setts:—*Ballymurtagh*, *Ballygahan*, *Tigroney*, *Cronebane*, and *Connary*, which were let as "Copper Mines," and when first worked any poor pyrites raised was run into spoil. But about the year 1840, on account of the high price of sulphur, the character of the mines quite changed, as instead of being working for copper they became "Sulphur Mines." While the great demand for sulphur lasted, vast sums were made by the different adventurers; and, as in late years, there was a demand for iron ore, it also was a considerable source of profit. The great demand ceased about the year 1865, and afterwards the mines rapidly declined, and now little or nothing is being done.[2]

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[1] From Boate's history and Petty's maps it would appear as if Wicklow was a *terra incognita;* the first authority does not mention anything in it (the Co. Wicklow), while the second leaves the track a blank in his maps.

[2] The decline was gradual; the Spanish ore—with its 48 units of sulphur, 3 of copper, and 25 dwt. of silver, also an unlimited supply—gradually drove the Irish ore out of the English market; although for a long time the Irish "Coppery Pyrites"—40

The future prospects of these mines is an important consideration, and the present state of the different setts is therefore of interest. This will be briefly given from the N. E. to the S. W. of the channel.

Southward of Wicklow town, at the north-east end of "The Channel," is the *Ballycapple Sett*, in the townlands of Ballycapple and Ballard. The iron bark of this lode, which seems to have been very rich, was worked in the time of the Chamneys, the ore being carried on horseback to the works at Ballynaclash in Glenmalure. Some of it also seems to have been smelted in bloomeries in the vicinity of the mines, as their sites are still to be seen From the fragments in the attals, the "true lode" seems to be a coppery pyrite, but it was never worked. Just before the working ceased the miners were driving up from the south an adit to drain the mine. This was recently opened, and was found to end some ten or fifteen fathoms short of the lode. In 1852 trials were made in search of "copper ore," but with what results are not recorded. In 1875 a few tons of iron ore were raised, also brownish ochre, from the back of the lode in Ballycapple Hill. The latter, and the "black stuff" from some of the ancient bloomeries were exported to be used in the purification of gas. Up to the present time only the iron back and ochre have in part been removed, some stones giving high analysis; they, however, do not represent the average iron ore. The true lode itself, does not appear to have been broken, and its nature, value, and extent have still to be proved.

Between Ballycapple and Kilmacoo, a distance, in a S. W. line, of about three miles, the country is very little known. In it the regular Channel has not been found; but in places there are small veins of copper, sulphur-ore, lead, and zinc. It is possible that the trials made have been too much southward; because in the townland of Rockfield, about a mile N. N. E. of Kilmacoo, is an assembly of "shode stones," very similar to those that elsewhere occur in connexion with the Channel; the Channel may be therefore heaved northward.

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units sulphur and 2.50 copper—held its own. As a general rule, the Irish pyrites is much more free from arsenic than the Spanish ore, and therefore more suitable for the manufacture of the pure sulphuric acid.

S. E. of Kilmacrea Pass, in the north part of Coolanearl, is an old shaft; but there is no information in connexion with it.

The break a little east of Kilmacoo, or Connary cross-roads, cuts off the Mineral Channel, and heaves it, apparently northward as just suggested. On the Channel between it and the Ovoca river lie the EAST OVOCA MINES. Of these mines an exhaustive description was published, in 1879, by P. H. Argall, formerly agent of the Magpie.[1] They are in two groups—to the north-eastward, *Kilmacoo*, *Connary*, and the *Magpie*, or *East Cronebane*; and to the south-westward, *West Cronebane* and *Tigroney*.

In the north-east division there are two main lodes, irregularly wedge-shaped, the walls closing in depth on account of the hanging or south wall, standing more perpendicularly than the foot or north wall. The Mineral Channel and the lodes were formerly supposed to have been deposited contemporaneously with the associated rocks, but recent research has shown, that although the general direction of the lodes may be more or less with the strike of the "country rocks," yet the Channel and lodes always cross the latter, though sometimes at a very small angle, while in depth both dip at a greater angle than the "country rocks."

The north lode is principally sulphur-ore, often coppery; it is more or less friable, and accompanied with soft ground. In Connary, south of the lode, there is a massive rib of quartzose rock, with native copper disseminated through it, which is not found in the Magpie. Between the lode and its "gossan" (iron and ochre) there was an auriferous argentiferous lead "Gossan lode," remarkable as in it there were minerals not found in the underlying lode. In Kilmacoo, in old times, there appears to have been an adit that was driven in from the north slope; this, however, has been closed up for years. Between Connary and the Magpie there is a N. and S. left-hand heave, along which there was a lead lode. The lead in the Gossan and Cross lodes was worked in very old times, while the rest of it was abstracted during the present century. Some of the sulphur ore still remains, but not much, as the "Wedge" has been bottomed in different places; it is, how-

[1] *On the Ancient and Recent Mining Operations in the East Ovoca District.*—Scientific Proceedings, Royal Dublin Society, 1879.

ever, possible that, if sunk on still further in depth, the walls might again separate.[1]

The south lode occurs in Kilmacoo and the Magpie, it being principally "blue ground," in which are the veins and pockets of *Kilmacooite* or *bluestone.* This peculiar mineral appears to be an admixture of the sulphides of zinc, lead, iron, copper, antimony, arsenic, and silver, with a trace of gold; but it varies greatly and rapidly. It was known in Weaver's time; as the Coppery ore in Madame Stephens' lode is mixed with it; while a vein was cut in the "Lodge level." Weaver seems not to have been able to utilize it, while at the present day it cannot be economically reduced. At the present time the typical ore has only been proved in the places above named; but a variety was found in West Cronebane by Argall, and Haughton mentions a variety that occurred in Ballymurtagh, the latter in places being very auriferous (page 206). If, however, the economical reduction of this ore is hereafter understood, it is probably that elsewhere in the courses of "blue ground" it may be found.

A careful analysis of this ore is most important, as, on account of the various constituents and their peculiar relations to one another, hand specimens are very different, some being very rich, others very poor; and unless the greatest care is taken in selecting specimens for analysis, the results may afterwards be most disastrous to the well-being of a mine. This caution is necessary, as the analyses published show that in most cases the ores examined were *picked rich specimens*, which although of interest to the mineralogist, are pernicious to the mine, as they lead to false hopes, which can never be realized. The Magpie has been so-called from the black and bluish-white ground found in the lode associated with the ores.

To the westward of the Magpie, between it and West Crone-

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[1] In the deepest working (Williams' shaft, Tigroney) the walls appeared to be again separating. In some of the Cornish mines when the Copper lode had died out, on sinking deeper, tin ore was found. This appears to be a consideration in connexion with the future of these mines, more especially as tin must exist somewhere in the county, having been found in the "streamings" for Gold. Furthermore, in the Magpie shaft the lode in depth was cut out by a Granyte protrusion; and, if the lode continues in depth, the mineral contents might possibly change. If these mines hereafter gave new riches in depth, they might be economically worked, by driving up Weaver's deep or "Boat level."

bane, is the tract called the *Yellow Bottoms*, or *Dead Ground.* The latter name was probably given to it in Weaver's time, because the "standing copper lodes" of West Cronebane do not extend into it. In connexion with it are Madame Bulev's, and some other mineral lodes; while from explorations made in 1879 and 1880, it would appear that there is also a large sulphur-ore lode, the back of which forms the ochre beds that were worked in 1882, and subsequent years, for the manufacture of paints.

The south-eastern division (*West Cronebane* and *Tigroney*) is cut off by a fault from the Yellow Bottoms, the nature of which has not yet been explained. In connexion with this fault all that can be positively stated is, that the Mineral Channel to the eastward and westward have characters markedly distinct, the lodes having different characters, while some of the minerals found in the first are absent from the second.

The main lode in West Cronebane and Tigroney is wedge-shaped; hard sulphur-ore and some coppery-ore occurring in lamina parallel to the foot wall; while south of it there were "standing lodes"—thin long cake-like masses of coppery-ore. The standing lodes are all worked out; principally in the early part of the present century. The main sulphur lode has been extensively worked of late years, and very little ore now remains; unless it is possible that in depth the wall again separated (*see* note, last page). About 1880 the irony back of a lode was proved in the wood south of Castle Howard; it appearing in the position where the North lode of Ballymurtagh ought to be found.

In the county, north of Cronebane and Connary, are minor veins: one, *Lion's Arch lode*, north of Castle Howard, having been worked profitably between 1870 and 1880 for iron and sulphur-ore. Some of the other lodes might be remunerative if worked in connexion with one of the larger lodes.

A deep level was commenced near the old Glebe in Shroughmore, which was to have been carried south-east till it cut the Connary lode: unfortunately this was not continued, as there are reasons for supposing that it might have cut more than one lode in its course.

Copies of the plans, and sections of the majority of the old and new workings in the EAST OVOCA MINES are lodged in the Mining Record Office, London.

To the west of the Ovoca River are the West Ovoca Mines, including the two Ballygahans and Ballymurtagh.

Ballymurtagh and Lower Ballygahan are divided from the East Mines by a channel of dead ground in the Ovoca River Valley, which heaves (left hand) the latter northward. In these are the North and South sulphur lodes; while south of the latter are the Standing coppery lodes, all the lodes being in character respectively similar to those in the Tigroney and West Cronebane setts. There is a slight left-hand heave near the boundary of Ballymurtagh and Ballygahan. East of this, in the latter, the north lode carried coppery ore only; while in the Ballymurtagh North lode there is a gossan of iron, or ochre, on a rich sulphur lode. Here there was no gossan lode; but in places between the gossan and the lode was a large "vug" full of water. Much of the ore in these lodes is still unbroken.

In Ballymurtagh, between the North and South lodes, there was a shoot of ore, "Pond lode:" this is worked out. In the South lode, Ballymurtagh, the ore has been broken more or less to 110 fathoms below the Margaret level, and in Ballygahan to 70 fathoms below the adit, the deepest working in the first being 24 fathoms below the deepest in the last. At the breast of the workings in Ballygahan, at 60 fathoms, the ore gave 37 units of sulphur, and 4·4 units of copper, the course being over 11 fathoms wide, the south hanging wall not having being reached. Ballymurtagh and Ballygahan would be more profitably worked as one mine; because at any time, on account of the underlie of the South lode, the portion in Ballymurtagh could be undercut by a level in Ballygahan.

In Ballymurtagh South lode there was a lenticular mass of an ore allied to Kilmacooite, it in places being very auriferous.[1]

In no place in either Ballygahan or Ballymurtagh has the bottom of the lode being reached; while in both there are good breasts of unbroken ore. Copies of all the plans and sections of these mines are lodged in the Mining Record Office, London.

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[1] In Culvert's analysis, in five out of six, there is a return of gold, while in the analysis by Apjohn and others no gold was found. This is another example of the care with which specimens should be selected. Culvert's specimens were from this peculiar ore, which did not represent the true lode, and therefore raised a false hope.

In the Mineral Channel south of the Ballygahan portion of the lode there were Standing veins of coppery ore; but as these were followed westward they joined into the South lode of Ballymurtagh. These coppery lodes for the most part are worked out.

In the county immediately north of Ballymurtagh and Ballygahan there are a great many small veins of sulphur-ore, with a few of lead. Various trials have been made on the sulphur-ore lodes, none of which are of good promise; but some of the lead lodes seem to have been worked by the "Old Men."

Westward of Ballymurtagh, in Upper Ballygahan, Killeagh, and Ballymoneen there are various traces and small veins, on which numerous trials have been made without success, looking for the continuation of the mineral channel in the strikes of the Ballymurtagh lodes, as the Ballymurtagh lodes, seem to become poor, as if they approach a left-hand heave; the trials seemingly ought to have been made more to the south, in the townland of Ballinapark.

Farther south-west are the SOUTH WEST OVOCA, or KNOCKNAMOHILL MINES, including the portions of the Channel in Ballymoneen, Ballinapark, and Knocknamohill. Here there also seems to be both North and South lodes. The gossan, or iron back of the first was extensively worked in the Chamney times; and in late years a large "parcel," of ore, was raised to the east, in Ballymoneen ("Hodgeson's shaft"). The ore was rich, giving 75 units of iron; but when worked the iron was "cold short." Mr. W. E. Adeney, Analytical Chemist, Royal College of Science, who has lately analysed the ore, states:—"The fact of its going cold short was due to the phosphoric acid; but by the method of Gilchrist now employed, phosphoric acid is no detriment; on the contrary, in ores that contain little silica, as this one does, phosphoric acid is an advantage, and, I think, this ore might be tried by Gilchrist's method with great success."

In these townlands the lode under its iron back (gossan) does not appear to have been broken, and the nature of the minerals is unknown. A shallow level, apparently to drain the Iron Mining, was driven up northward from the mearing of Ballinapark. The Channel and lode to the westward is cut off in Knocknamohill by a fault.

The south lode appears to have been unknown to the "Old

Men." About the year 1840 it was sunk on by Crockford, and some 400 tons of coppery-ore raised; but the adventurer getting into difficulties, the mine was abandoned, and no further work was done.

South-west of Knocknamohill, in the Valley of the Darragh Water, or Aughrim River, there are unknown complications; the Mineral Channel not having been found from where it is cut off by the Knocknamohill N. & S. fault till it is met with again south of the valley, in Ballycoog.

To the south of the Darragh Water are the CARYSFORT MINES. From Ballycoog to Moneyteigue, north of Croaghan-Kinshella the Mineral Channel can again be traced, having in it two or three lodes of sulphur or coppery-ore. They, however, are not continuous, being shifted three or four times, by left-hand heaves.

There were old workings at Ballycoog and Moneyteigue, especially the latter, for iron ore; while in late years various trials were made by the Carysfort and other Companies, some iron and good coppery-ore (8 to 12 units of copper) having been raised at Moneyteigue. In the other places the works were far from satisfactory, as they evidently were entrusted to incompetent hands; and after vast outlay during a number of years, none of the lodes have been proved, except at the surface; consequently their nature in depth is quite unknown.

To the north-west of Croaghan-Kinshella there are mineral indications, but no trials appear to have been made.

To the south of this portion of the Mineral Channel, in the tract south of the Darragh Water, and west of the Ovoca River, various small veins of lead, sulphur, and coppery-ore have been found; but none seem to be of much promise. Some lead ore was raised at Ballintemple, westward of Woodenbridge, but the vein was small.

Although the Mineral Interests in the county, as is so general elsewhere, is now at a low ebb, they must at some time mend. It is, therefore, expedient to give a brief forecast of what may be the prospects along the line of the Mineral Channel.

Ballycupple and *Ballard.*—The lode under the iron and ochre back unbroken.

Rockfield.—The origin of the "shode stones" still to be traced out.

Kilmacoo and *Connary.*—The Kilmacooite may become a profitable ore. In depth the walls of the main lode may separate. There is also the chance of a lode being found to the northward between Connary and Shroughmore.

Magpie.—The Kilmacooite may become valuable, and in depth the walls of the main lode may separate.

Yellow Bottoms.—A sulphur-ore lode probably exists under the ochre bed.

West Cronebane and *Tigroney.*—The walls in depth may separate. The North lode in Castle Howard Wood is totally unbroken.

Ballygahan Lower and *Ballymurtagh.*—The deep ore in the South lode unbroken. In the North lode only a small portion of the ore abstracted.

Ballinapark, *Ballymoneen*, and *Knocknamohill.*—The iron back of the North lode is more or less removed, but the lode appears to be unbroken. The South lode only broken in one place.

Ballycoog, *Ballinasilloge*, and *Moneyteigue.*—The lode proved in Moneyteigue, where iron and coppery-ore has been raised; but elsewhere the nature of the lodes have not been satisfactorily proved.

From the foregoing notes it will be seen that there are other places in which prospects are not discouraging. It cannot, however, be said, without further trials, that there is a prospect of these making future mines.

The other mines, also well known, are those on the lead lodes in connexion with the great Granyte intrude in the northern portion of the county, they being principally situated in the tributary glens to that of Glendalough and in Glenmalure. Luganure, or the upper portion of Glendasane, one of the branches from the first, being the principal centre of industry.

In the beginning of the century the mines in these and a few of the neighbouring glens were opened up by Weaver, who described the lodes in his Paper read before the Geological Society of London, May, 1818. In 1853 they are further described by W. W. Smyth, vol. i., part iii., *Records of the School of Mines;* but subsequent to the latter there were valuable reports on individual mines by others, especially those by Griffith. Since Smyth wrote, no new lodes seem to have been found, the works

up to late years being on those then known, or on branches from them.

These lodes seem all to have been in the region of the junction between the Granyte and Schist, in the first being more or less rich, in the latter in general poor or nearly valueless; while in a few places at the contact there were good bunches of ore. In Glendassan, associated with the *galenite*, were *cerusite*, *sphalerite*, and *pyromorphite*, the lead ores (galenite and cerusite) giving eight to ten ounces of silver to the ton. Of the numerous veins the largest was that called the Camaderry lode. In late years, on account of the low price of lead, the works gradually slackened off till 1880, when they came to a stand still.

The lead veins in Glendalough were remarkable, being associated with chalybite (carbonate of iron), the latter in one place being eight feet wide. The workings on these lodes have been discontinued for years, the lead veins being too small to pay at the low prices for lead.

In Glenmalure there are numerous small lodes, or strings of lead, all of which have been more or less explored. The only mine that gave returns was that at Ballinafunshogue, to the east of the River Avonbeg. This, when in full work, was stopped, the lease having expired, and excessive terms, it is said, being asked for a renewal. The ores in the lode were galenite, barytes, sphalerite, and specks of chalcopyrite.

To the west of the Avonbeg, at Baravore, there are appearances of a good lode; but only partially explored. Here barytes was in quantity, and of very good quality. In Clonkeen with the lead there was chalybite.

Westward of Glenmalure, at the North Prison, Lugnaquilla, is a lode of lead, very favourably reported on by the late Henry Robinson; but it is very difficult of access. Lead also occurs to the southward of Lugnaquilla, at the waterfall, northward of the Aghavannagh Barracks.

Eastward of Glenmalure lead is recorded, at Cullintra Park and at Loughs Dan and Tay, &c. Lewis states the lode at Lough Dan is worked out.

The localities for the gold and tin found in this county are given in the Lists, Part I. In connexion with a "gold digging" there are the *quartz reefs*, the *shallow placers*, the *deep placers*, *dry*

gulch placers, and *shelf or bar placers.* [Possibility of gold being found in the Co. Wicklow.—*Proc.*, R.D.S., February 19th, 1883.] In the Wicklow diggings the reefs have been unsuccessfully looked for; while the gold was principally worked in the "shallow placers," and in a few cases in the "dry gulch placers;" but neither the "deep" or "bar placers" have been explored, at least in modern times. Tin was found in some of the "shallow placers."

Fluorspar is recorded as occurring both crystalline and massive in the Glendalough Mines; but the quantity is not stated. It is now valuable as a flux for iron.

NOTES IN PRESS.

Donegal, Ordnance sheet 58.—South side of Glenaboghill Lake, one mile N.N.E. of Fintown; a N.E. and S.W. lode of Silverlead.

,, ,, 50.—At the head of the Owenbeg, Glendowan, a thin lode of lead.

BOG-IRON-ORE.—Mr. W. E. Adeny states: "After it has been used for the purification of the gas, the ammonium salts are first extracted from the spent ore by means of water; the fine ferriferous powder deposited being very valuable in the manufacture of brown paint. The residue then dried and burnt for sulphuric acid manufacture. The cinder left after burning off the sulphur is often sent back to be re-used for washing gas."

XXVI.—THE "CŒCAL PROCESSES" OF THE SHELLS OF BRACHIOPODS INTERPRETED AS SENSE-ORGANS. By PROFESSOR SOLLAS, LL.D., D. Sc., &c.

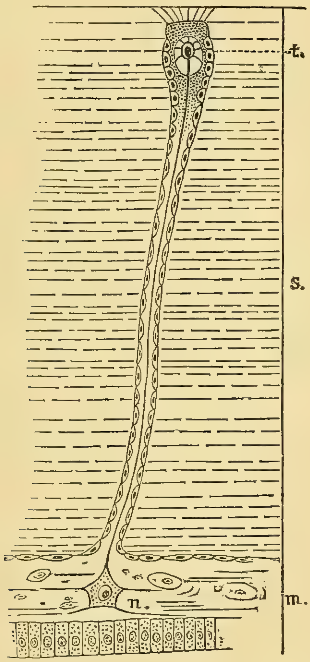
[Read, November 18, 1885.]

In the course of investigating the Tetractinellida, brought home by H.M.S. *Challenger*, I had occasion to cut thin slices of the decalsified valves of a specimen of *Waldheimia cranium* which had been overgrown by an incrusting sponge. On examining these slices under the microscope with a view to determining the structure of the sponge, I was at once struck with the resemblance of the processes filling the tubules in the shell of this Brachiopod to sensory aid organs; and as on referring to Van Bemmelen's[1] account of the Brachiopod shell I found no mention of this, I thought it might be worth while to draw up the following short account:—

The tubular processes which vary greatly in length, and though occasionally simple, are usually branched, and sometimes repeatedly so, are transparent and colourless for the greater part of their course, bearing small but evident nuclei in the walls indicating the epithelial cells of which they are constituted. In the centre they show traces of an axial fibre, visible both in transverse and longitudinal sections, and probably of nervous nature, as it can be traced into continuity with the nerve cells of the mantle. At the outer end of the tubule its appearance rapidly, almost abruptly, changes, presenting a single large finely-granular cell with a large oval nucleus and spherical nucleolus; both cell and nucleolus stain deeply with hæmatoxylin. Closer investigation reveals the presence of numerous additional nuclei, some of which appear to belong to the epithelium of the outer wall, which thus continues, if this be so, as an investment to the terminal cell. In other

[1] Over den Bouw der Schelpen van Brachiopoden en Chitmen, Docter-Dissertation, 1882, Van Bemmelen.

cases there appears to be more than one terminal cell. The inner end of the terminal cell appears to be prolonged into a fibril, which can sometimes be traced into continuity with the nucleus on the one hand, and with the axial fibre on the other. The outer end of the cell abuts against the lower face of the periostracum, and thus ends smoothly and abruptly, not giving off hairs or any other processes; the fine striation which occurs at the end of the cell, and which has been figured and described by Van Bemmelen, being of another nature. The periostracum imme-



m = mantle. *n* = nerve cell. *s* = shell. *t* = end of cœcal process.

diately over the end of the tubule appears to easily separate from that surrounding it, since I find the end organs adherent by means of the overlying periostracum to the base of the incrusting sponge, while the rest of the periostracum has disappeared from around them, *i.e.*, been torn away in the process of cutting.

Tracing the cœcal tube inwards, the axial fibre is continued into the nervous layer of the mantle, as already mentioned; the

walls, on the other hand, continue into the pavement epithelium investing the exterior of the mantle, of which they are demonstrably nothing else than an extension. This is most plainly shown in very young processes to be met with near the point margin of the mantle, and which consist of but a few cells; the terminal cell being of a hemispherical form with the rounded surface outwards, and evidently nothing more than an enlarged epithelial cell.

The cœcal tubes of *Waldheimia cranium* are, therefore, epidermal outgrowths, with a large granular invaginated terminal cell, which at one end is continued into a nerve fibril, and at the other covered by a transparent chitinous layer, separating it from all external influences likely to serve as stimuli, except that of light. It would therefore appear that the transformation of this form of radiant energy into nervous disturbance is the function of the so-called cœcal processes. Still further investigation is however necessary before this view can be fully adopted, especially as a serious objection to it exists in the absence of anything like pigment in the terminal cells. Better material than that at my disposal may, however, throw further light on this and on other points which in my sections remain obscure.

XXVII.—*ZINC AND ZINC ORES*, THEIR MODE OF OCCURRENCE, METALLURGY, AND HISTORY, IN INDIA; WITH A GLOSSARY OF ORIENTAL AND OTHER TITLES USED FOR ZINC, ITS ORES, AND ALLOYS.

By V. BALL, M. A., F. R. S., Director of the Science and Art Museum, Dublin.

[Read, December 15, 1886.]

Some years ago I presented to this Society several Papers on certain of the mineral productions of India, regarding which no general accounts founded on the geological examination of the country had up to that time appeared. Since then I have written a volume on the *Economic Geology of India*, in which is incorporated all that could be ascertained regarding the useful minerals of the country up to date. In the preparation of that work, the more or less casual references to the occurrence of useful minerals which are to be found in the writings by travellers in India during the past 2000 years were as far as possible explained and relegated to their proper places. Owing partly to the great extent of the literature which exists in the languages, both ancient and modern, of many different nations, and also owing to the fact that many of the works known to me were not accessible in Calcutta when I wrote the *Economic Geology*, it was unavoidable that the references to the original authorities were incomplete. I have, however, during the past five years devoted a large amount of time to reading up all that I could meet with bearing on the subject, and in that pursuit have acquired, or had opportunities of seeing, a number of rare old books on India which have proved a valuable mine in which the information is no doubt widely scattered, in so far as any one subject is concerned, but in which much information regarding many different subjects is to be found—the result being that I have been enabled to collect a considerable store of facts, which I hope to publish from time to time in a series of Papers more or less similar to the present.

The subject of this Paper is, as I think I shall be able to demon-

strate, one of particular interest, in consequence of the fact that zinc, as an isolated metal, has only been known in Europe in comparatively recent times,[1] though several of its combinations with other metals were made known to Western nations by the traders who brought them from the far East at very remote periods of the world's history.

In several parts of India traces of zinc ores have been met with (chiefly the sulphide or blende) in association with ores of copper and other metals; and to this circumstance may perhaps be attributed the fact that Abdul Fazl, the author of the *Ain-i-Akbari*, in an enumeration of metals which were obtained in the rivers of the *Subah* of Lahore, includes brass.[2] It is conceivable that this refers to a metal obtained in smelting an undesigned or natural combination of ores, which was really brass instead of copper, and hence the ridicule with which the statement has been criticised is perhaps not exactly deserved.

That brass was discovered first by such an accident appears to be generally admitted. Afterwards it was manufactured by the addition of natural calamine to molten copper, and even, when that was not obtainable, by the addition of artificial calamine scraped from the chimneys of smelting furnaces.[3] Upon this subject, and its connexion with the alchemist's search for gold, some information will be found in Beckmann's *History of Inventions*.[4]

Beckmann, who regrets the scantiness of the available information about India, says that the zinc came from China, Bengal, Malacca, and the Malabar Coast, and adds that an Englishman went to India in the 17th century to discover the process used there in the manufacture, and returned with an account that it was obtained by distillation *per descensum*. I have not yet been able to identify this Englishman.

By a curious fatality, the principal zinc mine in India, of which we have certain knowledge, was described by Col. Tod,[5] incidentally,

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[1] The name is first mentioned by Paracelsus in 1616, though the metal appears to have been known to Albertus Magnus in the 13th century.

[2] Gladwin's Ed., vol. ii. p. 109.

[3] Known to Albertus Magnus in the 13th century.

[4] See Bohn's Ed., ii. p. 32.

[5] Rajasthan, vol. i. p. 504.

as a *tin!* mine, and this statement has led Lassen[1] and others to conclude that in early times tin was produced in the peninsula of India itself; but we are not at present justified in believing that there was at any time a largely-worked source of tin in that country, and we are therefore driven to the conclusion that all the tin exported from Indian ports was first brought to them from Tenasserim or the Malayan Peninsula and its islands.

This mine is at Jawar or Zawar, in the Udepur State of Rajpootana. Tod states that the annual revenue derived from it amounted to a sum exceeding £20,000 (222,000 rupees); so that the produce must have been considerable, and independently the extent of the excavations points to the same conclusion.

The mine of Dureeba, or Daribo, which Tod also mentions as a *tin* mine, yielding a revenue of 80,000 rupees, was, it is believed, a copper mine.

The ores at Jawar, so far as is known, consist of the carbonate or Smithsonite,[2] and argentiferous galena, but no traces of tin ore have been met with, nor is there any local tradition of tin ever having been produced there. The including rocks are believed to be quartzites of the Arvali group of the transition series.

The following account is derived from a Paper published in the year 1850 by Captain Brooke, who acquired most of his information from one of the native miners, still living on the spot, who had worked in the mines before the famine of 1812–13, when they were closed. He described the ore as occurring in veins three or four inches thick, and sometimes in bunches, in quartz rock. The pure ore, being very friable, was pounded, freed from quartz, and placed in crucibles some eight or nine inches high and three inches in diameter, with necks six inches long and half an inch in diameter. Into these necks the metal sublimed on the application of heat in the following manner: the mouths being fastened up, the crucibles were inverted and placed on a charcoal furnace. It took three or four hours to complete the fusion of the ore. It is

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[1] Lassen, *Indisch Alt.*, vol. i. p. 232, was, however, aware that zinc occurred in India, as he refers to Captain Brooke's Paper, quoted below.

[2] Much confusion exists, owing to the application of the term calamine to both the hydro-silicate and the carbonate. See Dana's *Mineralogy* on this subject of nomenclature.

stated that the crucibles used to crack if any fragments of the matrix were inserted into them with the ore.

An account of these mines was published in 1872,[1] which is merely of value here as testifying to the great extent of the excavations, and to the former wealth and importance of the place, which is afforded by ruins of forts, temples, &c. As for the ores, the information about them is not only scanty, but probably incorrect: it is that "veins of almost pure lead ramify through the primitive rock, whilst beautifully-coloured ores of the mineral sparkle overhead. Silver is obtained in small quantities, whilst gold has been found, it is said, on several occasions." It is possible that the so-called almost pure lead was argentiferous galena; but the gold is probably mythical.

So far as I know, these mines have not yet been described by the Geological Survey of India; but a description by Mr. Hacket of the geology of the States of Rajpootana, which adjoin Udepur, and in which the Arvali rocks are strongly represented, was published some years ago.[2]

There are reasons for supposing that some of the mines in southern India, especially those in the Karnul district at Gazalpully, or Baswapur, may have produced zinc,[3] and it is possible that metal from these local sources may have in early times supplied the workers at Beder with their material. Other reported occurrences of zinc ores in India are, so far as is known, of trifling importance.

There can be no doubt that zinc, as a constituent of various alloys, has been largely used in India since the earliest times recorded by history; thus in the 6th century Sopater mentions brass as being obtainable at Calliana, a port in Bombay; and as it is certain that a large amount of these alloys reached India by means of the trade with China, I shall presently refer to what is known of that part of the subject.

In Materia Medica, too, especially in the treatment of cutaneous diseases, evidence is available of the employment of preparations of zinc since very early times in India.

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[1] *Indian Antiquary*, vol. i. p. 63.

[2] Vide *Records of the Geological Survey of India*, 1881, p. 279.

[3] See Mallet, *Records, Geol. Surv. India*, 1881, p. 305, and *Economic Geology of India*, pp. 284 and 312.

An analysis by the late Dr. Walter Flight[1] affords some interesting information of one manufacture in which zinc is largely used. He says that the well-known "Bidri" ware of Beder, in Hyderabad, consists of a metal into which plates of silver about the thickness of writing-paper are pressed into, the undercut grooves forming the pattern. The two metals adhere, and are then finely polished. The materials forming, I. a box, and II. a bottle, gave the following results :—

	I.	II.
Zinc, by difference, . . .	94·552	93·516
Copper, ...	3·920	3·278
Lead, ...	1·400	2·171
Gold, ...	—	0·690
Iron, ...	0·128	0·345

These proportions seem to suggest a doubt as to the material being a specially prepared alloy. It might, perhaps, result from the reduction of an ore of zinc containing the other metals in combination. The presence of these metals would account for the surface-colouring, which is brought out probably by vegetable acids. Whence the alloy comes is not known; but even if imported now, it is not improbable that the art of making the ware was discovered when a local source was known.

In Colonel Yule's *Glossary of Anglo-Indian Words* this "bidri" alloy is described as being a kind of pewter, containing one-fourth of copper; and he adds that a short description of the manufacture is given by Dr. George Smith, in the *Madras Lit. Soc. Journal*, N. S., i., pp. 81–84, and that the ware was first described by Heyne in 1813. Possibly one or other of these authors, whom I cannot now refer to, may give some information as to the source from whence the metal was obtained; but that the true "Bidri" of to-day, of which we have examples here in the Museum, consists mainly of zinc cannot be doubted.

It has been suggested by General Cunningham[2] that the alloy of copper and nickel of which the Bactrian coins, found so abundantly in the Punjaub, were made, was imported from China. He

[1] *Journal of the Chemical Society*, April, 1882.

[2] *Numismatic Chronicle*, 1873 (3), 13, N. S., No. li. p. 187.

thinks it possible, also, that the "Indian brass, as white as silver," mentioned by the poet Krinagoras, a contemporary of Strabo, and the "white iron," of which 100 talents were presented, by the Oxydraceæ and Malli, to Alexander, at the junction of the five Punjaub rivers, may both have been Chinese alloys of nickel. With reference to the latter, I venture to suggest that it may have been Indian steel, or so-called *wootz*,[1] which we know in the earliest times was a substance considered worthy of being presented to kings. Indian white iron, as contrasted with black iron, was mentioned by Homer. Rather than suggest that this Indian white iron, supposing it not to have been steel, was not the produce of India itself, I would name two other alternatives—one being that it was zinc, or an alloy of that metal, derived from the above-described mines; secondly, if it really was an alloy of nickel, I think it just barely possible that both it and the material of the Bactrian coins may have been derived from certain mines in Rajpootana,[2] where traces of nickel are known to exist, together with cobalt, the latter being worked to a small extent to the present day. That an extensive trade existed between China and India in very remote periods is, as already mentioned, a well-established fact, and my object in referring to the matter is to show the possibility of the above-named materials having been obtained in Indian mines, as that is an aspect of the question somewhat overlooked hitherto.

China.—In the early centuries of our era a western carrying trade by the Chinese was continued from some unknown earlier period. It extended as far westwards as the Persian Gulf, and to this trade, in the first instance, may be attributed the introduction of zinc and its combinations from China into Europe. Subsequently, though there is a record of Chinese vessels visiting Ormus in the 15th century, it became contracted, and the Chinese fleets ceased to go beyond the ports of Ceylon and those of the coast of

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[1] Its Sanscrit name was *vag-ra,* a title also applied to thunderbolts and diamonds, in the same way that the term *Adamas* appears to have been used. It has been recently shown by Colonel Yule (*Glossary*), that *wootz* is in reality not the name of steel in any Indian language. He attributes its origin to a clerical error, or misreading, for *wook*, representing the Canarese *ukku*, steel. It first appears in a Paper, by G. Pearson, M. D., in *Phil. Trans.* for 1795.

[2] *Economic Geology of India,* 324–326.

Malabar, where they met the fleets of the various nations—at first Phœnicians, Greeks, Romans, Arabs; afterwards Portuguese, Dutch, and English, which successively had possession of the commerce.

Now, although I have shown that an actual source of zinc exists in India, and was possibly worked long before the 17th century, it is undoubtedly the fact that much of the zinc which was shipped by the vessels of these various nationalities at Indian ports had been first brought from China to be bartered for Indian, or, it may have been, European commodities. Hence it is not always safe to assume that the articles, though shipped at Indian ports, and bearing their names, perchance, or other names of Indian origin, were really products of India itself.

As examples of the confusion which has arisen from similar causes, I may quote the case of two localities where diamonds were obtained as merchandise, with the result that the countries in which they were situated often appear enumerated, erroneously, as producing diamonds themselves. Thus, Ceylon[1] is spoken of as affording diamonds, and the report, though perhaps partly due to the false diamonds which are there made of white sapphires and zircons, is probably mainly attributable to the fact that diamonds brought from Masulipatam, and other parts of the Coromandel coast of India, were on sale there. Similarly, the diamonds purchased by traders in Malacca, and other older ports of the Malayan peninsula, were in all probability received first from Borneo, and to some extent, perhaps, from India too, just as it is possible that Borneo may also have contributed to the Ceylon supply. It should be added, however, that the name Malacca was used in the time of Linschotten[2] for Borneo, and hence much confusion by subsequent writers, as I shall explain on some future occasion.

To follow up all the information now available as to the occurrence of zinc ores in China would involve a very considerable amount of space, and its treatment here would not precisely belong to the specific object at present in view.

An early account[3] of the process followed in the manufacture

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[1] By Kazvini, in *Ajaib-al-makklakat*. See *J. A. S. B.*, vol. xiii. p. 632, and many other authorities.

[2] *I.e.* the end of the 16th century.

[3] Sir G. Staunton's *Lord Macartney's Embassy to China*, 1747, vol. iii. p. 382.

of zinc in China may, however, be quoted :—" *Tu-te-nag* (*i.e.* the name by which it was known in India) is, properly speaking, zinc extracted from a rich ore or calamine. The ore is powdered and mixed with charcoal-dust, and placed in earthen jars over a slow fire, by means of which the metal rises in the form of vapour in a common distilling apparatus. The calamine from whence this zinc is thus extracted contains very little iron, and no lead or arsenic, so common in the cadmium of Europe, and which extraneous substances contribute to tarnish the compositions made of it, and prevent their taking so fine a polish as the *peh-tung* of China."

Colonel Yule, in his *Glossary* (Art. *Tootnague*), quotes a number of authorities who mention this substance as being an article of trade from China to India. He points out that the name *tootnague* is not only applied by the natives of India and in commerce to the *peh-tung*, or white copper of the Chinese, but that, like spelter, it is applied loosely to zinc or pewter (*peh-yuen*, or white-lead of the Chinese).

He also quotes the following, which, for convenience of reference, are inserted here :—" M. Joubert[1] of the Garnier Expedition, came to the conclusion that the Chinese *peh-tung* was produced (in Yunnan) by a direct mixture of the ores in the furnace." And " Wells Williams[2] says, ' The *peh-tung* argentine, or white copper of the Chinese, is an alloy of copper 40·4, zinc 25·4, nickel 31·6, and iron 2·6, and occasionally a little silver : these proportions are nearly those of German silver.' " Further information is to be found in the work by St. Julien and P. Campion, quoted below.[3]

The following glossary is not exhaustive, as there are many-named combinations mentioned by Savot and other early writers, into the nature of which I do not propose to enter at present. Savot's work, especially, contains some interesting information on the subject.

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[1] *Voyage de Exploration*, ii. 160.

[2] *Middle Kingdom*, Ed. 1883, 19.

[3] *Industries Anciennes et Modernes de l'Empire Chinois*, 1869, p. 75.

Glossary of some Oriental and other Titles used for Zinc and its Alloys.

Bidar, Bidri (Hindustani).—This is described by Forbes (*Dict.*) as the metal of which *hukkas* are made (at Beder). It has been shown by Dr. Flight's analysis, quoted on p. 325, to consist principally of zinc. Curiously enough, Forbes gives no name directly for zinc in his dictionary. *Kaskat* he names as a variety of "bidar." An article on "bidri" will be found in Colonel Yule's *Glossary*, as stated on p. 325.

Birinj, or *Pital* (Hindustani).—According to the *Ain-i-Akbari*, this metal (brass) is of three (? two) kinds: one kind is malleable without being heated in the fire, and it is made of two seers of copper to one seer and a-half of *rotutia*. The other kind is not malleable, and it is used in casting; this is compounded of two seers of copper and one seer and a-half of *rotutia*. The proportions being identical in each case, the translator has probably made a mistake (*see* Gladwin's ed., vol. i. p. 41.)

Cadmia (Latin).—The name "cadmia" seems to have been applied by Pliny to several ores containing zinc, from which brass was made, and also to the furnace products, whether of calcination or sublimation, found when ores containing zinc were roasted. In some measure it therefore bore the same signification as calamine, but it covered a wider range, being applied to ores which contained no calamine, but which, when roasted, produced the furnace calamine (*see* Beckmann, *Hist. of Inventions*, Art. *Zinc.*)

Calamine.—See for suggested origin of this name the Chinese "*Yu shih*," p. 331. By some authors the name is still applied to the carbonate (Smithsonite), but Dana advocates its being reserved for the hydro-silicate.

Calen, Calaem, Calay (Hin. *Kala'i*, i.e. Tin).—Under one or other of the above names authors have sometimes apparently referred to zinc; but these titles are, strictly speaking, corruptions of the proper name for tin. And in some cases it is doubtful whether the writers merely applied the wrong name to a substance which was either zinc or pewter, or gave the right name to the substance—tin—which they thought was a different metal, as it was some little time after Indian tin reached the markets that its identity with

the European tin, which had been imported into India by the Greeks and Romans, &c., came to be fully realized.

Hasht Dhat (Hindustani) (lit. "eight metals")—as described in the *Ain-i-Akbari*, consists of a mixture of gold, silver, copper, tin, iron, lead, *rotutia*, and *kanseh*, the last being a kind of bronze, consisting of copper and tin in the proportions of 4 : 1 (*see* Gladwin's ed., vol. i. p. 40).

Khar sini (Arabic) (= Alkali of China) is the name given by Kazvini to zinc in the 13th century, according to Newbold (*see* *J. A. S. B.*, vol. xiii. p. 656).

Pital (Hin.).—See *Birinj*.

Rotutia.—In the *Ain-i-Akbari* this is enumerated as one of the seven known metals, the others being gold, silver, copper, tin, iron, and lead. The translator, in a footnote, calls it "a kind of native pewter." As elsewhere mentioned, Abdul Fazl includes brass (and *rowey*, an alloy of copper and lead) in the list of metals obtained by washing in the rivers of *Subah*, Lahore (Gladwin's Ed., vol. i. p. 40, and vol. ii. p. 109). *Tutia*, according to Colonel Yule (*Glossary*), is the Persian for oxide of zinc, and is the base of the word *Tootnague*, q. v.

Spelter, *Spiauter*, *Speauter*, *Spealter*, *Speltrum*.—According to Beckmann, this word came to us, with the commodity, from India; but the derivation of the word seems doubtful. "Spelter" is at present used vaguely for zinc and pewter, and as such appears in the ordinary commercial trade returns of India.

Teou-shih? (Chinese).—This name of a metal occurring at Tseh-kia (*i.e.* Takka, on the Chenab River, in the Punjab) is mentioned in the *Si-yu-ki*, a Chinese work, compiled in A.D. 646, and of which an edition has recently been edited by Mr. Samuel Beale, who says (p. 165): "The *teou-shih*, of which such frequent mention is made by Hieun Tsiang, is said to be a compound of equal parts of copper and calamine" (*see* Julien). Medhurst (*Dict.*) suggests that it is native copper, which might seem not improbable, except that it occurs in some of the lists together with copper (*teou*).

Tomback (Hindustani).—This is a variety of brass formed of zinc and copper. At one time it was regarded as being of more value than gold. It was imported from Indo-Chinese countries. Colonel Yule, in his *Glossary*, gives several quotations as to its uses

in Java, Borneo, and Siam. The terms pinchbeck and prince's-metal appear to be applicable to the same compounds as *tomback*.

Tootnague (Hindustani).—Colonel Yule (*Glossary*) divides the meanings attached to this name under two headings, one being equal to the *peh-tung* of the Chinese, the composition of which is given on p. 328 ; while the other is a loose application to either zinc or pewter, corresponding, therefore, with the common commercial and very vague term "spelter." According to Beckmann, it was applied to a mixture of tin and bismuth. This was probably when tin from the Straits was first introduced to European commerce by the Portuguese, in the 15th century. *Calaem*, which was also used, was the more correct title.

The word is derived from the Persian *tutia*, an oxide of zinc, a title which is commonly used now in European works on Materia Medica for the artificial oxide.

Yu-shih (Chinese), which is mentioned, as well as *teou-shih*, in the *Si-yu-ki*, a Chinese work compiled in the year A.D. 646, is considered by Medhurst to be calamine, used in the formation of brass. Mr. S. Beale, who suggests its identity with the *cadmia* of Pliny, says that it was possibly called calamine from the name of a port Calamina, at the mouth of the Indus, from which circumstance the Chinese described it as coming from *Po-sse* (*i. e.* Persia). I have not been able as yet to trace the name Calamina on the Indus, but Calliana—a name for a port in Bombay—is mentioned by Sopater (a traveller of the middle of the 6th century) as a place where brass was to be obtained (*vide* Sir Emerson Tennant's *Ceylon*, vol. i. p. 545).

XXVIII.—ON THE EXISTING RECORDS AS TO THE DISCOVERY OF A DIAMOND IN IRELAND IN THE YEAR 1816. By V. BALL, M.A., F.R.S., Director of the Science and Art Museum, Dublin.

[Read, April 16, 1883.]

[From the above given date it will be seen that nearly four years have elapsed since this Paper was read. The delay in its publication has been due to the fact that I was desirous of obtaining some further information on the subject, and, if possible, of availing myself of some opportunity for making a personal examination of the locality where the discovery is stated to have been made. Although up to the present I have not obtained any additional information, and have been unable to make the projected examination, I have been led to delay the publication no longer, as it may direct attention to the subject, and so lead to the required information being acquired. Moreover, inquiries have been recently addressed to me as to what the facts of the case really are. Imperfect, and it must be said inconclusive, as they appear to be, they are, therefore, now recorded for future reference.]

For some time I have been engaged in the collection of materials for a general correlation of the diamond-bearing deposits throughout the world, and have already amassed a considerable amount of information on the subject. Regarding some localities, however, the accounts are geologically defective, and I must defer for the present attempting to draw up a general statement of the facts. In the meantime, however, I would direct attention to a record of the discovery of a diamond in Ireland, as the subject is likely to prove of special interest here.

In Karl Ritter's *Erdkunde Asien* (vol. vi., published in 1836) I first met with the statement that a diamond had been discovered in Ireland. Subsequently I found it repeated by several different writers, and quite recently I have been enabled to consult John Murray's work on diamonds, which was published in 1831, where the fact appears to have been first recorded. The passage is as follows:[1]—"A diamond has also been found in Ireland, in the bed of a brook flowing through the district of Fermanagh. It possesses a red tint, and was brought to a lady

[1] Murray, *On the Diamond*, p. 30. London, 1831.

resident there by a little girl who said she had picked it up in the bed of the brook. The bearer was rewarded with sixpence by the lady, who had been in the habit of collecting pebbles, &c., from the rivulet. This rough diamond was afterwards submitted by the lady to Mr. Mackay, an eminent jeweller of Dublin, who pronounced it to be a diamond; and not long after the opinion of the late Mr. Rundell of Ludgate Hill was obtained, who valued it as a diamond worth twenty guineas in its then rough attire. On ascertaining this the lady issued a notice desiring to see the girl again, but she never afterwards made her appearance, perhaps fearful to lose the sixpence, for it appears that even this remuneration was only granted conditionally. We received our information in person from the Rev. Dr. Robinson, of the Royal Observatory at Armagh, a gentleman of high scientific attainments, who had the gem in his possession, and was well qualified to judge."

Before meeting with this passage I was told by Lord James Butler that the diamond was still in the family of Sir Victor Brooke, to whom I accordingly wrote, and he kindly favoured me with the following reply, which differs from Murray's account only in so far as regards immaterial points, such as the names of the jewellers who handled the stone. But in order that the evidence should carry conviction as to the original matrix of the diamond having been in the rocks of the neighbourhood, further proof as to the actual position and circumstances with which it was found seems desirable. I am led to make this remark since I have twice seen specimens of fossil bones obtained from fishermen's houses in Ireland, which were said to have been dragged up in the nets, but which, if they had not first been dropped from vessels into the sea, were, probably, brought from far distant localities by some travelled friends of the fishermen.

Sir Victor Brooke's letter is as follows:—"The diamond was found in the year 1816 in the Colebrooke river (which takes its rise in the mountains between Monaghan and Fermanagh, and flows into upper Lough Erne). It was brought to my grandmother, Lady Brooke, by a little girl who had been searching for pearls. Lady Brooke placed it in her inkstand, where my father, who had just returned from Brazil, observed it by chance. He was struck with it, and said he suspected it to be a diamond, and took it up to West, the jeweller, in Dublin. West pronounced it

to be certainly a diamond. My father then took it to Storr and Mortimer, who confirmed West's opinion, and it was set in Wicklow gold either by West or Storr and Mortimer. It is now an heir-loom in my family. It is a nice diamond, not quite so large as a swan-shot; its only flaw being that it is slightly tinged with yellow. There can be *no doubt whatever* about the authenticity of the story."

The rocks traversed by the Colebrooke river, in its upper reaches, consist of beds referred to the Old Red Sandstone, and apparently the Silurian formation is also represented close by. Now, excepting South African localities, it would seem that the original matrix of the diamond, in most of those countries where it is found, is in rocks of these ages or somewhat older. It is true that in Borneo both diamonds and gold are found in tertiary deposits; but there can be little doubt that neither the one nor the other originated in them, but were derived from older palæozoic rocks. In India, too, the diamonds are generally found in diluvial detritus, which is, however, largely made up of materials obviously derived from rocks of possibly Devonian or Silurian age.

In Brazil, according to a lately published account[1], the mines at Grao Mogol and other localities are in a bed of palæozoic age, and at Parana they occur in Devonian sandstones and conglomerates. Mr. O. A. Derby, the writer of this account, considers that the diamonds, like the pebbles with which they are associated, are all of detrital origin. But at Sao Joao the diamond is believed to occur in its original matrix, namely, a vein of quartz called *barro*, now decomposed, but containing iron and tourmaline. This vein traverses unctuous schists and itacolumites, which are believed to be of Cambrian age.

Thus, in so far as the age of the rocks goes, there is sufficient resemblance to the conditions of diamond occurrence in other parts of the world, for saying that there is no inherent improbability in the supposition that the diamond which is the subject of this notice may have originated near the spot where it is stated to have been found.

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[1] *American Journal of Science*, February, 1882.

XXIX.—AN EXPERIMENTAL METHOD OF DETERMINING MOMENTS OF INERTIA. By GERALD STONEY, B.A.

[Read, December 15, 1886.]

Of the integrals which are found to be useful to engineers, probably that which is most frequently required is the moment of inertia of a plane round an axis in the plane—

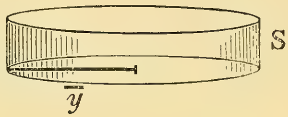
$$I = \int y^2 da,$$

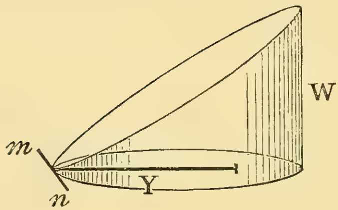
where y is the distance of an element of area da from the axis round which the moment of inertia is to be taken. On the value of this moment of inertia depends, among other things, the calculation of the transverse strength and deflection of beams; of the strength of long pillars; of the distribution of the pressure on the foundations of retaining walls and abutments, &c. In all such problems it is necessary to determine the moment of inertia of the cross-section; and where this is of complicated form the calculation is often difficult, so that it would be a boon to engineers to have some simple experimental method of arriving at the result. Even where the moment of inertia is determined by calculation, it is often useful to have an experimental method of checking the correctness of the work.

The following method of determining the moment of inertia occurred to the author when engaged in employing the graphical method of investigating the distribution of pressure along the overhung bearing of a shaft. In this method ordinates being erected proportional to the pressures at various points along the bearing, the centre of gravity of the figure so formed is a point on the line of pressure. In the analytical method the same result would be reached by the help of a moment of inertia, and the comparison of these two methods suggested the following experimental way of determining moments of inertia:—

Cut from the pillar, of the section of which we want to find the moment of inertia, or from a model of it, a parallel slice S, between two cross-sections, and a wedge W between a cross-section

and a sloping section, intersecting along $m\,n$, a line parallel to the axis round which the moment of inertia is to be taken. This





latter, in nearly all the cases required by engineers, is a line passing through the centre of gravity of the cross-section.

Balance S and W on knife edges, and so determine $\bar{y}$, the distance of the centre of gravity of S, and Y, the distance of the centre of gravity of W, from $m\,n$. Then will the moment of inertia of the cross-section round $m\,n$ be

$$I' = AY\bar{y},$$

where A is the area of the cross-section. From this it at once follows that the moment of inertia round an axis parallel to $m\,n$ through the centre of gravity will be

$$I = A\bar{y}\,(Y - \bar{y}).$$

This last is the quantity required in engineering problems, and, to determine it, it is only necessary to measure Y and $\bar{y}$ as above, and to determine A, the area of the cross-section.

To prove this—Let y be the horizontal distance of any point from $m\,n$. Let z be the breadth of the section at that distance from $m\,n$. Let A be the area of the cross-section. Let V be the volume of the wedge W. Let α be the angle of the wedge W. Let $\bar{y}$ be the distance of the centre of gravity of the cross-section S from $m\,n$. Let Y be the distance from $m\,n$ of the centre of gravity

of the wedge W. Let I' be the moment of inertia of the cross-section round $m\,n$. Let I be the moment of inertia round a line parallel to $m\,n$, through the centre of gravity of the cross-section. Then will

$$I' = \int zy^2 dy. \tag{1}$$

Again, $$VY = \tan a \int zy^2 dy,$$

which, by (1), $$= \tan aI'. \tag{2}$$

Also $$V = \tan a \int zy\,dy = \tan aA\bar{y}. \tag{3}$$

From (2) and (3) we get

$$I' = AY\bar{y}.$$

And since, by a well-known theorem,

$$I' = I + A\bar{y}^2,$$

it follows that the moment of inertia round a line parallel to $m\,n$ through the centre of gravity of the cross-section will be

$$I = A\bar{y}\,(Y - \bar{y}),$$

which is the theorem to be proved.

In order to find the positions of the centre of gravity of the sections, I have found it convenient to use a table, levelled, and with a row of points standing in a straight line, and projecting $\frac{1}{8}$ inch. The section is then balanced on these points, and when the position is found at which it is exactly balanced a slight pressure, if the section is not of hard material, drives the points into the section, and then with a straight-edge a line over which the centre of gravity lies can be drawn. A sharp knife-edge is in some cases more convenient than a row of points. The edge of the wedge is to be made parallel to the knife-edge, or row of points, and to facilitate this adjustment it will be found convenient to draw upon the table a number of lines parallel and perpendicular to the row of points.

With wooden models, made with ordinary care, I found that the moments of inertia by experiment and calculation did not in any case differ more than 2 per cent., and were generally correct to 1 per cent. This for almost all engineering purposes is of quite sufficient accuracy, and in fact is, wherever the section is of

irregular shape, of greater accuracy than can be obtained by calculation, unless great detail is gone into. Thus, in calculating I for an ⌶ plate girder, the ordinary approximate method (in which a sixth of the web is added to the flanges) gave for the moment of inertia

$$I = 806{\cdot}1.$$

A very carefully detailed calculation made

$$I = 852{\cdot}0,$$

showing that the approximate method erred by 5·4 per cent. My experimental method gave with a wooden model

$$I = 856{\cdot}9,$$

which is only 0·57 per cent. out. This is one of several examples which show that the experimental method here recommended gives in complicated cases much closer results than the methods of calculation which are practically used by engineers.

It should be observed that the wedge need not be one which comes to an edge, but may be of a truncated form. In all cases the line $m\,n$, from which Y and $\bar{y}$ are to be measured, is to be the intersection of the faces of the wedge, and in this case lies outside the pillar, instead of being a tangent to it. However, the nearer to the pillar that it can be conveniently placed the greater will be the accuracy of the determination. Of course the surfaces of the wedge must be flat, and the model of the pillar out of which it is made of uniform section and density. $m\,n$ may have two positions, since two lines can be drawn, touching the pillar, and parallel to the axis round which the moment of inertia is wanted. It is advisable to place it at the side of the pillar which is the broadest, if there is a difference in this respect.

XXX.—NOTE ON A BRILLIANT METEOR SEEN AT STRASBURG ON THE 15TH OF AUGUST, 1886. BY J. EMERSON REYNOLDS, M.D., F.R.S.

[Read, December 15, 1886.]

On the evening of the 15th of August last I happened to be at Strasburg, Alsace, and observed the fall of a meteorite which emitted a brilliant light in its passage through the atmosphere. The colour of the light was peculiar and suggestive; hence this short note on the phenomena.

At the time the meteor was observed to fall the sun had set, for it was five minutes before eight by local time; the sky was cloudless, and the atmosphere beautifully clear. The meteorite seemed to enter the atmosphere from the west, at a point which appeared equidistant from the zenith and horizon, my post of observation being the verandah of the Hotel National, which is on the side of the large Platz opposite the new Railway Station. The meteor seemed to fall directly over the main portion of the station, which was almost exactly due west of my position, and the path of the meteor was slightly inclined to the horizon, tending south.

The light was very bright, and, as often observed in these meteoric flashes, was greenish; but the impression it produced on eyes practised in observing flame colouration was similar to that caused by a *boracic acid* flame, rather than by one whose colour was due to copper.

I am well aware that copper has been found in some meteorites, whereas boron has not been detected in any of those whose analyses I have seen. On the other hand, the presence of a small quantity of boron might be easily overlooked unless very careful search for it were made; moreover, carbon and silicon in various states of combination have been found in meteorites, and boron is so nearly related to both these elements, that its occurrence in meteorites is certainly not improbable.

I hope, then, that in any future analyses of meteorites the possible presence of boron may be kept in view, and search made for the element in these strange wanderers from interstellar space.

XXXI.—*OLDHAMIA.* By G. H. KINAHAN, M.R.I.A., Etc.

[Read, December 15, 1886.]

The organic origin of *Oldhamia* has been disputed before now: even at the present time some of the American and Continental geologists seem to dispute it. Such authorities, however, as Forbes, J. R. Kinahan, Harkness, and Baily, have carefully examined it, and I have accepted their opinions; but at the same time no one is infallible, and there may be a possibility, although, to my mind, an improbability, that they may be wrong.

As the subject is of interest, I propose to put forward all facts, as far as I know them, in connection with the occurrence of *Oldhamia*, some of which appear to me conclusive that it must be of organic origin, while others may suggest that it may be a mineral structure.

At one time it seemed to me to be remarkable, that very often the *Oldhamia* is better developed in shales near an intrude of *Quartz-rock* than elsewhere. This, however, on going over the evidence, now appears to be more apparent than real.

In the west portion of Ireland the Cambrians are so much altered that all organic remains are obliterated; it is, therefore, only in eastern Ireland that these can be found. The localities for Cambrian or supposed Cambrian in this portion of Ireland may therefore be given beginning to the north, and in connection with each, stating the peculiarities.

In the north of the Co. Down, bordering Belfast Lough, are green and purple rocks that appear to be unconformable with the associated Ordovician rocks: these rocks are so like those of Bray Head that DuNoyer classed them as Cambrians. In them *Oldhamia* has not been found; nor as far as I am aware are there in connection with them intrudes of *Quartz-rock.*

In the Co. Longford, to the east of Granard, there are also more or less similar rocks that seem to be overlaid unconformably by the associated Ordovician rocks. The character of these rocks led Foot and myself to suspect they must be the representatives of

the Bray Head Cambrians. In these no *Oldhamia* has been found, although we searched them very carefully; nor is there any intrude of *Quartz-rock.*

In Howth promontory, Co. Dublin, Wyley classed the rocks as Cambrians, while subsequently J. R. Kinahan found at Puck Rock *Oldhamia antiqua.* (?) The specimens I found in this locality were on a smooth pale-green phylitic shale. I do not think there is an intrude of *Quartz-rock* in connection with this special locality; but elsewhere in Howth there are different intrudes of *Quartz-rock*, and in connection with them there are not any known localities for *Oldhamia.*

At Bray Head, Co. Wicklow, *Oldhamia* (*radiata* and *antiqua*) occur in numerous places. Those with which I am the more intimately acquainted are more or less in connection with the intrudes of *Quartz-rock;* some places, however, are not so.

At Greystones, south of Bray Head, *Oldhamia* has also been found; but my knowledge of these rocks is too scant to mention more about them. According to the map in this neighbourhood there are intrudes of *Quartz-rock.*

In Carrick Mountain, south of Glenealy, is the locality where *Oldhamia* was first found by Flanagan. Here it occurs as *O. radiata*, *O. antiqua*, and *O. discreta*, the latter being an intermediate form between the others, to which attention was first drawn by J. R. Kinahan (*Trans.*, Royal Irish Academy, vol. xxiii., p. 547).

At Flanagan's locality the *Oldhamias* occur in purplish shales like those of Bray Head, and in phylitic pale-greenish shales, the best marked specimens being in the latter. This locality is intimately connected with intruded cakes of *Quartz-rock.*

At Roney Rock, south of Courtown Harbour, Co. Wexford, alongside an intrude of *Quartz-rock*, in a thin bed of red shale, there is *O. antiqua.*

Farther south along the Wexford coast, at Cahore bathing-place, *O. radiata* occurs in a purple bed, like those of Bray Head; while at Cahore Head, *O. antiqua* occurs sparingly in a light-green phylitic shale. Here there are no intrudes of *Quartz-rock.*

Going still further southward, to the south-east and south of Bannow are other Cambrian rocks. These I have very carefully examined. Along the south coast the *Oldhamia* was only found in reddish, or slightly purplish, beds; the three forms, *O. radiata,*

O. antiqua, and *O. discreta*, occurring, but the last are those more generally found. In some places *O. radiata* occurred in lenticular pockets of limited extent; outside of which, *although the rocks were exactly ocularly similar*, not a trace of *Oldhamia* could be found. In other places *O. antiqua* or *discreta* might be mixed in the shales, but in general they were confined to thin beds, often not more than the eighth of an inch in thickness; and in this thin bed, and in no other, could the *Oldhamia* be found. Some of such thin beds I traced for nearly a furlong. These beds, as also the associated Ordovician rocks, have in them intrudes of *Quartz-rock*.

On the west coast of Bannow, close to the fault boundary of the Ordovician, in one four-inch bed of green shales, *Oldhamia* occurs sparingly. Here there are no intrudes of *Quartz-rock*.

In the foregoing I have specially mentioned the intrudes of *Quartz-rock*, because at one time I suspected there might be some connection between them and *Oldhamia;* but the above records seem to disprove such an idea. An *Oldhamia* bed has a certain look; and, after hammering bed after bed along the Wexford coast, I came to learn the exact appearance of those in which I would probably find *Oldhamia*, let the colour be reddish, purplish, or greenish.

Forbes, J. R. Kinahan, and Baily, from their investigations, come to the conclusion that *Oldhamia* has an organic origin; but my knowledge of such organization debars me from giving a positive opinion in their favour. Others say it is not organic; this also, my knowledge leaves me incapable of refuting. I can, however, legitimately take an intermediate ground. This is not exactly easy to name; but perhaps it may be called lithological evidence, it referring not so much to the fossils as to the rocks in which they occur; but before doing so I may refer to the forms of *Oldhamia*, and the more or less similar mineral forms.

Oldhamia is said to have a more or less similitude to some of the mineral markings on beds surface, joint planes, and other similar surfaces in rock structure. I have, indeed, seen some dendritic markings somewhat like *O. radiata*, but never any that I would mistake for it, as the points of the dendrites have an angular termination quite dissimilar to those of the *Oldhamia.* As to the impression of *O. antiqua* and *O. discreta*, I have never seen any surface mineral at all like them. *Oldhamia*, as it at

present is found, may be a mineral, and may even in part have lost its original form; but I contend that originally it was an organic form, but now mineralized, or having on the original form minerals built up. This subject was treated on nearly a quarter of a century ago in a Paper by our member Mons. A. Gages, who pointed out, in reference to the graptolites in some Ordovician black shales, that they were not only mineralized, but that at certain attractive places, such as points, bunches of crystals had accumulated. It appears scarcely necessary to point out that in some rocks, such as the Lias Coal-measure, &c., fossils are perfectly mineralized; while in others, such as the Cretaceous, they are not only mineralized, but have formed a nucleus round which foreign matter has accumulated.

If *Oldhamia* is a mineral structure, why does it occur under such peculiar circumstances? It has only been found in the Irish Cambrians, and in them it is confined to very limited strata; often scarcely the thickness of your nail, so that only those acquainted with its *habitat* can find it.[1] If it is a mineral, why does it not also occur in the exactly similar rocks adjoining these thin seams or layer, the layer or seam being identical in composition with the associated rocks?

Exactly similar rocks to those at Bray Head, in which the *Oldhamia* are found, occur in the Cambrians of other places in Ireland, and in those of England and America; yet in none of these places has it been found. Dendrites occur everywhere if the rocks are similar: why, therefore, if *Oldhamia* is a mineral, is it not similarly distributed?

Also in various places inside and outside Ireland there are rocks all made of *identical mineral constituents to those of the Irish Cambrians in which the Oldhamia is found.* The seare of Silurian, Ordovician, and Cambrian ages, and in none of them, except those of proved Cambrian age, has the *Oldhamia* been found. If it is a

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[1] The late Mr. E. Leeson, Fossil Collector on the Government Survey, and myself collected boxes of *Oldhamia* at Bannow; yet no one since, except Mr. Clarke, seems to be able to find it. At Cahore bathing-place Messrs. Baily, Leeson, and myself, carried away a bag full of fossils; yet twice since I was there, and I could not find the bed, although I know the exact place where it is. Similarly, Flanagan's original station on Carrick mountain was not known till a few years ago, when it was accidentally discovered.

mineral marking, it appears to me that it ought not to be confined to rocks of one formation, but should be common to all similar rocks, no matter what their age may be; similarly as we find dendrites in rocks of nearly every age.

As will appear from the first portion of this Paper, I am still quite open to conviction; but up to the present time the arguments put forward in favour of *Oldhamia* being of organic origin seem to me to be convincing. I therefore submit my views for the consideration of those who are of an opposite opinion.

XXXII.—NOTE ON A SPECIMEN OF ADULTERATED GUANO RECENTLY ANALYSED IN TRINITY COLLEGE LABORATORY. By EMIL WERNER.

[Read, December 15, 1886.

About two months ago I purchased at an establishment in this city a sample of Peruvian guano, the idea at the time being simply to examine the sample for uric acid, and if found comparatively rich in that body to obtain a further supply. The guano, however, on examination proved such an unusual specimen as regards adulteration and general inferiority that, at the request of Dr. Reynolds, I analysed the sample, and now beg to lay the results before the Society. With respect to the uric acid, which is a constant constituent of all good guanos, it was in this case conspicuous by its absence: not even a trace of it could be obtained when operating on four ounces of the guano.

So considerable was the adulteration, that, before commencing a complete analysis of the guano, it was necessary to pass it through a coarse sieve, a treatment which resulted in the separation of a quantity of foreign matter, in the form of pieces of granite, shells, &c., to the extent of twenty-five per cent. of the weight of the guano. The composition of the sifted guano is shown in the following analysis:—

Composition of Guano, previously freed from 25 °/o Adulteration.

Fixed constituents = 59·30 °/o,	Sand,	24·36 °/o		
	CaO,	11·65 °/o		
	P_2O_5.	14·29 °/o		
	SO_3,	2·05 °/o		
	K_2O,	5·13 °/o		
	MgO and nitrates,	1·82 °/o		
		59·30 °/o		
Organic and Volatile = 40·70 °/o,	Moisture,	13·51 °/o		
	Organic matter,	22·10 °/o,	containing nitrogen =	0·02 °/o
	Combined NH_3,	4·94 °/o	,, ,,	3·06 °/o
		40·55 °/o	Total nitrogen,	4·08 °/o

As is seen from the analysis, the amount of insoluble matter (sand) is still exceptionally high—nearly twenty-five per cent.: the

other constituents forming the fixed matter call for little or no comment with the exception of the phosphoric acid, which for a highly adulterated guano is much above the average; the magnesium oxide and nitrates, both of which were present only in very small quantity, were not directly estimated, the amount being determined by difference. A remarkable feature in this guano is the nitrogen, which, besides being naturally low, is entirely present in the form of ammoniacal salts: the minute amount of organic nitrogen, ·02 per cent., shown in the analysis, is no doubt due to partial conversion of the nitrogen of nitrates into ammonia during the ignition with soda-lime in presence of the organic matter.

In order to give a better idea of the extensive adulteration of the sample, I append below the calculated composition of a ton of the original guano.

Composition of a Ton of Original Guano.

	cwt.	lbs.
Sand, stones, &c. (adulteration),	7	89
CaO,	1	96
P_2O_5,	2	35
SO_3,	0	37
K_2O,	0	89
MgO and nitrates,	0	32
Water,	2	18
Organic matter,	3	57
Total nitrogen,	0	72
	19	77

The deficiency here is due to the fact that the calculation is not carried beyond pounds, and the ammonia in the guano is calculated to nitrogen only. The extensive adulteration in the above case is probably the work of the exporters of the guano; nevertheless the Dublin merchants who supplied it are not without blame, on account of either ignorance or carelessness in the selection and examination of their own purchase.

XXXIII.—ON A HYDROSTATIC BALANCE. By J. JOLY, B.E.,

Assistant to the Professor of Civil Engineering, Trinity College, Dublin. (Plate VII.)

[Read, June 9, 1886.]

The Hydrostatic Balance described in this Paper will be found illustrated on Plate VII., reference to which will enable its principle to be the more readily understood. It will be seen from figure 1 that it consists essentially of a vessel provided with one narrow tubulure opening, and suspended so that this tubulure is downward. Within is a second vessel; this vessel is closed, and is made of such slight material that it floats buoyantly in water.

A fine wire is attached to the lower end of this inner vessel, and passes through the tubulure. The tubulure of the outer vessel is on a nozzle which, when screwed off, and the vessel turned up, enables the space surrounding the float to be readily filled with water. When filled, and the nozzle replaced, the vessel is hung up, as in the figure, with the tubulure downwards. The diameter of the tubulure being only some 3 mms., there is perfect security against outflow: indeed the apparatus may be shaken or rolled about upon a table with impunity. When the balance is hung it is obvious that the inner vessel or float, in virtue of its buoyancy, will be urged to ascend within the liquid, and if, as in fig. 2, we hang a pan on the wire, and load weights on the pan, we find that we can add weights up to a certain point, when the pan descends with the sinking of the float within the vessel. This weight—just adequate to cause the pan to descend—we assume for the present to be constant, and equal W, suppose. W is evidently equal to the weight of a mass of water having a volume equal to the displacement volume of the float, less the weight of the float, of the wire, and of the pan attached to the wire. We can evidently ascertain, now, the weight of any mass not heavier than W. It is as if we were using a balance, one arm of which was loaded with an unalterable weight W. Thus, we place the substance to be weighed on the pan, and add weights till the pan descends.

At this point we know that a total weight W is in the pan. If the added weights amount to w, suppose, then $x = W - w$. Practically, however, W is a quantity variable with the temperature of the float and of the water, their densities altering to different extents. When, therefore, accurate results are required, we cannot assume any constant for the balance, but must determine afresh the force W with each determination of w. Or, what is the same, we proceed by simply removing x when equilibrium has been obtained with $x + w$, and substituting a weight w_1, so that equilibrium is again obtained, when w_1 is the required value of x. It is easy to guard against change of temperature in the brief interval necessary to effect the successive equilibrations. The process of weighing is, in short, the well-known one of substitution, and with the usual correction for unequal air displacements of the weights, and the substance is accurate to a degree depending on the sensibility of the float to indicate a small change of load, when the downward acting forces are very nearly in equilibrium with the upward acting forces. This consideration, *i. e.* the degree of sensitiveness possessed by the arrangement, next claims attention.

The system as described is, in principle, identical with the Nicholson hydrometer, used as a weighing machine, the latter arrangement being supposed inverted while still retaining the liquid. But the inversion of the hydrometer introduces this important difference, that the stem supporting the pan of the hydrometer, a compression member, becomes in the hydrostatic balance a tension member, and hence, stiffness being no longer a requisite, may be made of extreme fineness, and the retarding effect of the adhesion of the liquid on the wire at its circle of emergence is much reduced.

If, indeed, we assume the effect of this adhesion of the surface-film to increase in direct proportion with the radius of the circle of emergence, it would appear—observing that the tensional strength of the wire increases proportionally to the square of this radius—that the sensibility to a small fraction of the entire load falls off only as the square of the carrying capacity or load which the balance will bear. There is, in short, reason to expect that, as we increase the size and carrying capacity of this kind of balance, no diminution of the *fractional* sensibility occurs, but rather an

increase; the sensibility increasing approximately as the square root of the power of the balance. Thus, if we double the diameter of the wire, the balance will now indeed indicate nothing smaller than double the least weight formerly causing displacement; but, on the other hand, we may assume a quadrupled carrying capacity. This leaves out of consideration the effect of viscosity of the liquid.

The effect of viscosity will hardly be to reduce the sensibility, but rather to render more tedious the use of floats having large displacements. As, however, the tangential resistance to the motion of a solid surface, in the act of communicating a shearing strain to a liquid, is proportional to the extent of surface, and as this area increases at a slower rate than the volume inclosed by it, it appears that the tediousness attending operations is, again, not fairly assumed to be an attendant disadvantage which increases proportionally with increase of power of the balance The effect is indeed, probably, complicated by the presence of currents or eddies in the liquid.

As regards the effects of solid friction, contact between the movable and immovable parts might, indeed, be altogether avoided. Thus we might attach the wire externally to a flat cantilever, or flat spiral spring, so that it is retained in the centre of the tubulure by the horizontal rigidity of the spring, while the spring may possess such small vertical rigidity as not to interfere with the sensibility of the balance. It will be seen, however, from the figures, that this plan is not resorted to. It appears indeed unnecessary to do more than guard against contact down the wall of the tubulure; and this is provided for in the little projecting collar placed at the point where the tubulure meets the wider nozzle. The diameter of the passage here provided for the wire is about 1·5 mm.; the tubulure is about 3 mms. in diameter. The edge of the collar is sharpened to a knife edge all round, but just burnished smooth. With this arrangement, if the precaution be taken of using a smooth piece of wire, there appears but little retardation due to friction: this, doubtless, is partly due to the position of the collar within the liquid, the liquid acting as a lubricant. The effect of substituting a collar of burnished agate for the brass collar has been tried as in the balance, fig. 2, but with hardly appreciable gain in freedom. This little balance (fig. 2)

is represented in its actual dimensions. The float is a sphere of slight blown glass, weighing about 12 grammes, its diameter being about 6·3 cms. The outer vessel is of brass, parting, in a screw-joint, into hemispheres. For convenience of weighing by replacement, a double pan of slight brass is attached to the wire. This pan, together with the suspending gear, weighs about 11 grammes. The suspending wire traversing the surface of the liquid is of brass; its diameter is 0·09 mm. Its breaking strength is 403 grammes: the stress it is called upon to bear in the balance does not ordinarily exceed 120 grammes. A suddenly added or removed load might, indeed, act to some extent as a live load, and an increased stress result. Experience, however, seems to show that the strength is ample.

The balance is protected from draughts and sudden changes of temperature by a glass case, from the roof of which it depends, hanging freely.[1] The weights are introduced at a half door in the lower part of the case. The case needs no levelling screws.

At 6° C. the load carried in the pan, when equilibrium obtains, is 104·660 grammes. A change of load of 1 milligramme now causes displacement, and effects the descent or ascent of the pan. This balance then estimates the weight of 100 grammes to an accuracy of 100,000.

I must here observe, however, that working the balance to this degree of accuracy needs some care. Where estimation to an accuracy of say three milligrammes only is needed no special precautions are likely to be required. But with the construction shown in the figure for confining the travel of the pan and float there would seem to be an amount of adhesion before the pan is set in motion, which the small force of one milligramme will sometimes be unable to overcome. It is seen in figs. 1 and 2 that the double-eyed link to which the suspension wire is attached moves through—but without contact while moving—an eye which arrests its motion ascending and descending, affording it only about one centimetre run. The float thus never reaches either to the top or to

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[1] For very delicate work the further precaution of preserving the whole in a chamber not exposed to sudden fluctuations of temperature is, I find, necessary. Trouble from this source might doubtless be guarded against in all cases by surrounding the outer vessel with a non-conducting covering.

the bottom of the containing sphere, and adhesion at these points is avoided. The arrangement also obviously secures the advantage of guarding the fine wire against the effects of a weight erroneously added in excess of the power of the balance: indeed, if care is taken in adding and removing weights, the wire remains uniformly in the one state of strain. It is thus kept straight and true. Again, should the wire break, the descent of the pan is arrested by the eye and link. The arrangement, too, renders a slow motion of displacement very readily observable. I may observe, that the eye encircling the link is gapped at one point, to enable the link to be removed if desired. The construction of this link is simple, but necessitates the exercise of a little care in the process of equilibration, in order that the effect of adhesion at the link may be guarded against. The process of equilibrating is as follows:—The larger weights being added successively in the usual way, the equilibrium, we will suppose, determined to 1 centigramme, and the milligrammes reached, the 5 is added: if there is no immediate effect we grasp the link with the ivory forceps (used with the weights), and bring it down to the centre of its run, then release it, and observe its motion. It will most probably ascend; but there may have been adhesion between the link and eye, and we may find that it descends slowly. Its velocity of motion is in either case instructive after a little practice, and, as with the chemical balance, will enable us to save trials. If the link in the present case very slowly descends, we replace the 5 with 4 mgrs., and repeat the process of drawing down the link. We take care also to close the glass door while observing the motion. The result will be perfectly definite. It will ascend with the 4, suppose; descend with the 5, the starting point in each case being the centre of its run. And I may observe that it will, in this way, *indicate* a less quantity even than 1 milligramme. Thus recently using this balance with a new set of weights, I detected discrepancies in the 1 centigramme weights, as compared with the added milligrammes, which, on subsequently evaluating on a delicate chemical balance, were severally found to be ·7 and ·3 of a milligramme. It would, doubtless, be easy to arrange, so that the adhesion necessitating these precautions when weighing with the milligrammes would be eliminated. In fig. 3 two kinds of bearing are suggested: one—(*a*) where there is contact at two points; the other, (*b*) at one point only, when the

link is at either limit of its run. The last plan, too, would have the advantage of starting motion with the suspension wire in a central position.

If delicate weighing is to be carried out on these balances, it is necessary to use water that has been carefully filtered, as sediment will settle down into the tubulure, and clog the wire, adhering to it as it emerges from the liquid.

Experiments extending over several weeks showed that there is no reason to expect that under varying conditions of atmospheric pressure bubbles of air would be given off by the water to adhere to the float, provided the water is not supersaturated with air in the first instance. In my experiments the action, in this direction, of the variations of pressure was represented on an exaggerated scale under the air-pump to tensions of 50 mms. of mercury. This tension failed to withdraw visible bubbles from water previously freely exposed for a long period to the atmosphere. What dissolved air was withdrawn probably slowly emanated at the surface. The water was contained in a beaker, the float being represented by an immersed spherical glass vessel.

In the balance depicted in fig. 1 there is no provision for the effects of variation of temperature: any notable change of temperature will, with that construction, result in drawing air into the containing vessel, or expelling some of its contents. For occasional use, where the balance is necessarily filled and emptied frequently, as in travelling, this is of no importance, and will cause no trouble, if the precaution is taken of filling it with water appreciably at air temperature. The effects of temperature change will, indeed, be inconsiderable. Thus, taking the case of concentric spheres of brass, the inner displacing 179 grammes (diam. = 7 cms.), the outer having a diameter of 9 cms., and the intervening space filled with water, the effect of 1° C. change is a displacement of 14 cubic millimetres of water, about half a drop. The entry of a *little* air obviously does no harm: it simply rises to the top of the vessel, and in no way interferes with the truth or capacity of the machine. A little expelled water is easily dried off.[1]

[1] If the float be made of a substance having a low coefficient of expansion, such as glass, and the containing vessel be of material having a high coefficient of expansion, as brass, such dimensions may be given to the apparatus that the water space shall, with change of temperature, increase at the rate of expansion of water. In other

If it be desired, however, to render the arrangement nearly permanent, so that the operation of filling need but very seldom be repeated, the effects of temperature in expelling water or drawing in air must be met in some way. In the balance of fig. 2 this is done by providing the expansion reservoir shown surrounding the tubulure, and which communicates with the interior of the sphere by the narrow tube nearly reaching to the bottom of the reservoir, as shown in the figure. The large surface of water exposed in this reservoir bears to stand at a level above or below, by a couple of millimetres, the surface level of the water in the tubulure, as in the well-known experiment on capillarity in communicating tubes of very unequal bore. Hence, with rise of temperature the reservoir receives the expelled water; with fall of temperature it parts with some of its contents, and no water is lost. The annular reservoir communicates with the air by a very small perforation, and the loss by evaporation is very small.

To enable the balance to be readily filled, the ring by which it is suspended is arranged to screw out of a little tubulure communicating with the interior. The balance is filled in a few seconds by screwing out this ring, and immersing the sphere in a vessel of water; when no more bubbles ascend through the tubulure, the ring is screwed home, while the tubulure is still beneath the surface of the water. On withdrawal a little water runs out at the lower tubulure, till the head in the reservoir has been syphoned down to a position of equilibrium with the surface tension at the tubulure; the head is now still further reduced by applying a little bibulous paper to the tubulure, in order to provide for a subsequent rise in temperature.

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words, there would be no expulsion of water or entry of air with atmospheric variations of temperature. Thus for a spherical float in a spherical chamber, and assuming any desirable radius, r, for the float, let x be required radius of outer vessel; also let g, b, and w be the co-efficients of cubical expansion of glass, brass, and water, equating the increments of volume for a rise of one degree—

$$x^3 b = r^3 g + (x^3 - r^3)\, w;$$

taking $$g = 0{\cdot}000025;\; b = 0{\cdot}000054;\; w = 0{\cdot}00014;$$

$$x^3 = 1{\cdot}337 \times r^3.$$

But this affords unfortunately rather closely approximating values for x and r, as, for example, if $r = 2{\cdot}9$ cms. (vol. $= 100$ ccs.), then $x = 3{\cdot}2$ cms. Nor can I find materials affording much better results.

For the purpose of determining the specific gravities of solids, I use a little claw for supporting the substance under water, which can be suspended by a fine wire from a hook beneath the pan. The substance is first weighed in the pan, the claw being attached and immersed in a vessel of water placed beneath. On transferring the substance to the claw an increased weight will be required for equilibrium; the increase is obviously the weight of displaced water.

It is observable in the hydrostatic balance that, when the float is about to descend, the system is one of unstable equilibrium. The descent of the float is accompanied, in fact, by decreased displacement in the liquid due to the emergence of the wire, the effect being similar to that of an ever-increasing downward pull upon the float: once started, it tends to descend to its lowest point. If we provide a second wire, similar to the emerging wire, extending downwards, and dipping into a vessel of water, as occurs in the operation of determining specific gravity, the effect is in all cases obviously annulled. The correction is, however, with wire of the diameter 0·09 mm., quite unnecessary; the displacement of one centimetre of this wire representing but a small fraction, 0·06 of a milligramme.

I state these particulars at length, as I do not at present know of any other weighing machine in which a similar degree of delicacy may be so combined with the qualities of inexpensiveness and compactness, up to any ordinarily required power, as in this balance.

XXXIV.—ON A SPECIMEN OF SLATE FROM BRAY-HEAD, TRAVERSED BY THE STRUCTURE KNOWN AS *OLDHAMIA RADIATA*. BY PROFESSOR W. J. SOLLAS, LL.D., D. Sc.

[Read, November 17, 1886.]

THE structure known as *Oldhamia radiata* commonly presents itself in the form of discontinuous thread-like ridges radiating from a common centre, and lying in the planes of cleavage (coincident with the planes of original bedding) of a slate. A hand specimen in the collection of Trinity College, Dublin, cut transversely to the cleavage planes, shows, however, that the *Oldhamia* structure is not merely superficial, but extends across the cleavage planes into the substance of the rock.

In the hope of throwing further light upon this problematical structure, thin slices for microscopic examination were cut from this specimen, both parallel and transverse to its planes of cleavage. On placing these under the microscope all trace of the *Oldhamia* structure appeared to have vanished. An examination with the unaided eye showed, however, that it was still there, presenting itself as narrow, undulating, and branching bands of a lighter colour than the surrounding matrix: its appearance, however, varied in an extraordinary manner according to the direction in which it was viewed. Looked at obliquely in a strong light, the thread-like bands are brilliantly illuminated, and appear faintly coloured with spectral tints; looked at directly, the bands become fainter, and are less clearly distinguishable from the matrix. In certain positions the slice taken at right angles to the bedding has an appearance somewhat suggestive of shot-silk, and from the planes of cleavage, markings which somewhat remotely resemble in form the dendritic markings of Sutton stones extend into the surrounding matrix. These appearances, taken as a whole, suggest the presence of some mineral possessing high reflection or refraction arranged in more or less parallel planes.

My friend, Mr. Teall, to whom I submitted the prepared slides

has very kindly sent me the following notes on the mineral characters of the slate. By their insertion in this place my concluding observations will be made intelligible.

Bray-Head Slate.

"The main mass of the slate appears to be composed of quartz, sericite, and chlorite.

"The quartz and sericite are so intimately intermixed, and the individual constituents are so minute, that it is often extremely difficult to make out the boundaries of the crystalline elements in consequence of overlapping. The sericite scales are, however, easily recognisable by their more intense action on polarised light. They give colours when the quartz only polarises in neutral tints. When viewed in ordinary light, the sericite appears colourless. The scales show a tendency to an arrangement of their flat faces parallel with the planes of schistosity, as may be seen by rotating a section at right angles to the schistosity under crossed nicols. The greatest effect is produced when the planes of schistosity cut the cross-wires at an angle of 45°. The parallel arrangement of the sericite scales is, however, by no means rigidly observed.

"The quartz, so far as it can be examined, gives no evidence of a clastic character.

"The banding in the slate appears to be mainly determined by a variation in the amount of chlorite present. Some bands are very rich in chlorite, other bands contain only a very small amount of this mineral.

"The chlorite occurs in somewhat irregular scales and scaly aggregates. Sections at right angles to the easy cleavage are markedly dichroic (rays parallel to the cleavage cracks very pale yellow or brown, sometimes almost colourless; rays at right angles to the cracks rich bluish-green).

"In addition to the quartz, sericite, and chlorite, there are numerous minute spots which appear nearly opaque by transmitted, and white by reflected light. With a magnifying power of 500, these may be resolved into aggregates of more or less transparent grains, which resemble the common alteration product (leucoxene) after ilmenite. Sometimes these aggregates are seen in association with black grains, and it seems probable, therefore,

that they represent the alteration of ilmenite or titaniferous magnetite. A few scales of hematite also occur in the slides."

To this I may add that—(1) some fragments of quartz are present in the slate, which I think do undoubtedly show traces of a clastic origin; and (2) that a minute crack traversing the cleavage planes is shown in one of the slices; it is lined by chlorite on both sides, and filled with quartz containing minute scales of sericite, and numerous air-cavities, both spherical and crystal-shaped. Hematite is also present on the quartz; this shows that the formation of chlorite and sericite, and quartz, continued to take place even after the cleavage of the slate.

Examining the slices in the light of this description, one finds that the lighter-coloured bands, which correspond to the *Oldhamia*-structure, owe their distinction from the surrounding matrix to the presence of an excess of sericite scales; and that the curious shot-silk appearances are produced by the local deflections of these scales from parallelism with the cleavage planes, into directions tangential to curves, which are probably transverse sections of those long ridges which, when seen on the exposed surface of a cleavage plane, are recognized as the usual form of *Oldhamia;* and it would appear possible that these ridges are wrinklings of the cleavage planes produced during the shearing which led to their formation.

In addition to these corrugations, a structure resembling false bedding, on a small scale, is visible on some parts of the slices.

XXXV.—SUPPLEMENTARY REMARKS ON THE PREVIOUS PAPER ON *OLDHAMIA*. By PROFESSOR W. J. SOLLAS, LL.D., D.Sc. (With Plate VIII.)

[Read, December 15, 1886.]

The interesting discussion which the observations on *Oldhamia*, made at the last meeting of this Society, have elicited has induced me to offer the following supplementary remarks :—

1. The phyllades in which *Oldhamia* occurs consist of laminæ of mica (sericite), clastic grains of quartz, and chlorite.

2. The boundaries of the quartz grains are usually concealed in the usual thin slices of the rock by the chlorite : on treatment with hydrochloric acid, which removes the chlorite, they are rendered plainly visible.

3. The surface of the laminæ of the phyllades in which *Oldhamia* does not occur are smooth and even, and in transverse section the constituent minerals are found to be arranged in planes parallel to one another, and to the cleavage laminæ.

4. *Oldhamia* presents itself on the surface of the laminæ when it is present as rounded discontinuous ridges, which are without definite boundaries, and have the appearance of fine wrinkles.

5. When the phyllade is fractured obliquely to the cleavage laminæ, the *Oldhamia* markings are found to extend through the rock, as fine ridges or wrinkles, which mark the surface of oblique fracture in a similar manner to those of the cleavage face.

6. Transverse sections of such phyllades are wrinkled, conformably to the *Oldhamia* ridges, in minute undulating folds; the sericite scales lie with their faces in the surface of these folds, *i.e.* they are tangentally arranged. The width of the folds, measured from crest to crest, is about 0·4 to 0·8 mm.; the *Oldhamia* ridges have the same width.

7. The folds traverse several successive laminæ of the phyllade for a distance reaching and exceeding 2·0 mm. in length.

8. A series of such folds traversing several laminæ, regarded axially, has the appearance of a narrow band of different texture and colour to the rest of the rock: this is due to the reflection of light from similarly orientated flakes of mica.

9. In some cases a definite black line marks the surface of the undulations of a single lamina. This is produced by some ferruginous material soluble in hydrochloric acid. It is suggestive of the previous existence of an organism, the decay of which might have led to a deposition of some compound of iron. Further observation of cleaved specimens shows, however, that the ferruginous layer is not restricted to the *Oldhamia* markings, but occurs evenly over the surface of the laminæ.

10. More frequently the cleavage laminæ are coated with chlorite, which appears in some cases of greater thickness within the grooves which represent in imtaglio the ridges of *Oldhamia*.

11. In some specimens, straight or undulating, black lines run along the axis of a series of folds: these are produced partly by a change in direction of black rods, which in other cases run parallel to the cleavage laminæ, and partly by the in-filling of minute cracks formed along the axis of the folds.

12. In such cases the folds are usually sharper and closer together. Seven successive folds were counted in a distance of 0·8 mm. in one instance. The sericite scales are sharply bent in parallelism with the axis. In a hand specimen these sharp, sheared, or faulted folds produce an appearance of false bedding on a small scale.

13. They appear to represent a further stage in the folding of the rock, which commences with the broader wrinkles of the usual kind.

14. These appearances are remarkably similar to those of "ausweichungsclivage," described by Heim in his "Gibergsbildung."

15. They also suggest a resemblance to the modified bedding foliation and cleavage foliation described by Prof. Bonney in his last Presidential Address to the Geological Society of London (figs. 3 & 4, p. 70), but differ in the fact that the sericite scales are conformable with the foldings in the *Oldhamia* phyllades, but not in the quartz gneiss of Muchalls, where they lie at right angles to the chord of the folds.

16. While these observations tend to show that *Oldhamia* is but the incipient stage of "ausweichungsclivage," they throw no light on the remarkable radiate form of the markings.

XXXVI.—ON THE PHYSICAL PROPERTIES OF MANGANESE STEEL. By W. F. BARRETT, Professor of Experimental Physics in the Royal College of Science for Ireland.

[Read, December 15, 1886.]

At the British Association meeting in Aberdeen, in 1885, Mr. J. T. Bottomley read a brief note on "A specimen of almost unmagnetisable steel." As the magnetisation of iron was a subject on which I had worked for some time, Mr. Bottomley was good enough to hand over to me this remarkable specimen of steel for further investigation, at the same time giving me the name and address of Messrs. Hadfield & Co., Steel Founders, of Sheffield, the patentees and manufacturers of this steel.

Upon writing to Messrs. Hadfield, they furnished me with the result of a chemical analysis of their patent steel, which is as follows:—

Fe.	Mn.	C.	Si.	P.	S.
86·68	12·25	0·80	0·15	0·10	0·02 per cent.

Other varieties of this steel are manufactured, but this is the most generally serviceable. Specimens of this steel were first exhibited at the Institute of Mechanical Engineers in London in the early part of 1884, and a Paper describing this material appeared in the *Engineer* for February 8, 1884. From this Paper I make the following quotation:—

"It is sufficiently well known that manganese has been employed for many years in the manufacture of steel in various proportions, but anything exceeding 1 per cent., it has been generally believed, would render the metal under treatment worthless, and any further addition thereof in excess of this proportion has been considered impracticable. In fact, Dr. Siemens had stated publicly, on many occasions, that the use of manganese was simply a cloak to cover the impurities in steel making, that it covered a multitude of sins: and this was the general opinion of the steel trade. Messrs. Hadfield, of Sheffield, however, engaged in a long series of experiments and tests, with the object of discovering its

truth, and after a considerable expenditure of time and capital, discovered that by adding the ordinary ferro-manganese of commerce to iron or steel in such proportions as to produce in the steel or decarbonized iron under treatment a percentage of manganese varying from 7 to 20 per cent., that the most beneficial results could be obtained. Such percentage is regulated according to the purpose for which the steel is required. For instance, to produce a steel suitable for armour-plates and other purposes, as we mentioned last week, they add about 10 per cent. of rich ferro-manganese, containing, say, 80 per cent. of manganese, thus obtaining a steel containing about 10 per cent. of manganese. For railway purposes they add about 11 per cent.; for steel toys and tools, about 12 per cent. They pour this ferro-manganese into the molten steel under treatment, thoroughly incorporating it therewith, and then run it into ingot or other suitable moulds, and allow it to cool, after which it is ready for use, as it requires neither tempering, rolling, forging, nor hardening. This treatment of steel in suitable proportions, according to requirements, appears to be novel, and renders the steel so manufactured harder, stronger, denser, and tougher than most steel now manufactured, even when forged and rolled. This steel may, however, be forged and rolled in the ordinary manner. *For casting* it has the advantage that it possesses greater freedom from honeycombs and similar defects; but the most peculiar property is its great toughness, combined with extreme hardness. It is through this that the hitherto indispensable processes of rolling, forging, hammering, hardening, and tempering may be dispensed with, thus effecting for many articles an enormous economy in time, labour, and expense. In casting its fluidity enables fine steel castings to be made without misrunning, and approaching in smoothness iron castings.

"Amongst the samples of the steel placed on the table at the meeting of the Mechanical Engineers was a sample test bar containing 12 per cent. manganese, bent double when cold, though hard enough for turning iron; a sample from same ingot shows a tensile strength of 42 tons per square inch, with 20·85 per cent. elongation; several hammered pieces; a manganese adze, containing 20 per cent. manganese, just as it left the mould; an axe, containing 12 per cent. manganese, just as cast in the rough, had chopped through ½in. square iron. This, like the others, had not been hardened or tempered, only the edge ground."

In a Paper read before the American Institute of Mining Engineers in May, 1884, some tests of this steel were given, showing the extraordinary tenacity and hardness of the material. When hammered or drawn into rods it loses some of its toughness,

and becomes exceedingly hard. If now the steel be heated to a yellow or nearly welding heat, and then suddenly quenched in cold water, instead of becoming harder it loses some of its hardness, and becomes exceedingly tough, so that the effect produced upon manganese steel is just the opposite to that produced upon ordinary steel, which is of course rendered hard and brittle by sudden cooling.

It was important for the purpose of my investigation to obtain a specimen of manganese steel drawn into wire, and Messrs. Hadfield endeavoured to draw some for me. In this they did not at first succeed; so I begged Messrs. Rylands of Warrington, whose extensive wire-drawing works are well known, to make the attempt. They were good enough to oblige me, and, after several ineffectual trials, wrote:—"We gave the steel into the hands of our most experienced wire-drawer, a man who is accustomed to draw crucible steel wire; but he says that although he gave it every facility, putting only half a size on to it, the steel will not draw at all." After much time had been lost in these attempts, Messrs. Hadfield, at my request, once more undertook the task themselves; and I am glad to say they have now been completely successful. The specimens here exhibited for the first time are long lengths of manganese steel wire, No. 13 S. W. G., and also No. 19 S. W. G., of two kinds, hard and soft. I requested Messrs. Hadfield to let me know the method of wire-drawing they found successful, and the following is their account of the process adopted in drawing manganese steel into wire:—

"When first trying to reduce this material from the rolled rods into wire, it was attempted to draw it straight away from the rods; but, owing to its hardness, very little progress could be made, as the wire kept breaking in short lengths. Several methods were tried, such as softening it by annealing, as in ordinary wire; but this seemed to make very little difference.

"As exceedingly good bending tests had been obtained with bars of the same steel when heated to a yellow heat, and plunged into cold water, it was thought worth while attempting a similar experiment with the rolled rods before trying to draw it down into wire. The rods were coiled up, heated to a yellow heat over a smith's fire, and then plunged into cold water. It was then easily drawn into wire, starting with No. 7 gauge, when it was drawn to No. 9 with safety. This drawing

again took out the requisite ductility, and it was therefore necessary to again heat the wire, and plunge it in the same manner as before. By doing this each time the wire was reduced two numbers of the gauge; there was no difficulty whatever in drawing it to any desired fineness, the only point necessary being that the wire must be heated sufficiently hot before plunging into cold water, or the wire would be still too hard. The colder the water the better the result."

The composition of the manganese steel from which the wire was drawn is slightly different from the specimen I obtained from Mr. Bottomley. The analysis of the wire is as follows:—

Iron.	Manganese.	Carbon.	Silicon.	Phos.	Sulphur.
84·96	13·75	0·85	0·25	0·10	0·09 per cent.

I have now to lay before the Society the results of some of my experiments with this material:—

Density.—The density of the manganese steel wire, I find, is 7·81, that of ordinary steel being 7·717.

Hardness.—In its ordinary condition manganese steel is very hard. It easily scratches steel that is not hard-tempered.

Modulus of Elasticity.—The modulus of elasticity (Young's Modulus) was determined by direct stretching. Experiments were made with the ordinary hard manganese steel wire and with the same wire annealed by sudden cooling. A length of four metres was suspended from a well-constructed clamp of a new form, devised and made for me by Messrs. Booth, Brothers, of Dublin, and the readings were taken by an excellent cathetometer. The flexure of the support under the maximum stress was carefully tested and found to be inappreciable. An initial weight of 2000 grammes was kept on the wire, and additions were made of 10,000 up to 40,000 grammes; with the maximum weight there was no set, the index accurately returning to zero when the weights were removed. Three elongations were made in each of five sets of observations, the mean of the fifteen trials giving a modulus of 16,800 *kilogrammes per square millimetre.* Another set of observations were made with an initial stress of 5000 grammes; adding to this 38 kilogrammes, on and off, the mean of three sets of observations thus made gave a rather higher number, namely, 17,130 kilogrammes per square millimetre.

Mr. M'Cowan, B. Sc., the Demonstrator in Physics at the

College of Science, also took a set of careful observations; the number he independently obtained was somewhat lower, namely, 16,470 kilogrammes per square millimetre.

The mean of these three series of experiments is the same number as the mean of the first fifteen experiments, viz.:—

16,800 kilogrammes per square millimetre,

or 1680×10^6 grammes per square centimetre, which may be taken as the modulus of *hard manganese steel wire*. The diameter of the wire used was 0·98 millimetres, and the length under observation 3·455 metres.

The *soft* manganese wire was now tried. Six sets of experiments were made with three or four elongations in each, the mean of twenty elongations giving a modulus of

16,710 kilogrammes per square millimetre,

slightly below that of the hard wire.

These numbers are lower than I expected. Iron has a modulus of 18,610 kilogrammes per square millimetre. Steel wire varies from 18,810 up to pianoforte wire, which is 20,490 kilogrammes per square millimetre.

But this comparatively high rate of extensibility of manganese steel is for many purposes a considerable advantage, as it enables the material to give under a sudden stress without fracture.

Breaking stress.—Experiments in the breaking stress of the wire were now made. The dynamometer I used was tested and found correct. A comparative experiment was made with pianoforte steel wire, 0·027 inch diameter. This broke at a stress of 150 lbs., corresponding to a breaking stress of 117 tons per square inch. Ordinary steel wire has a breaking stress of 54 to 63 tons per square inch. The tenacity of the best pianoforte steel wire is the highest known, and amounts to 150 tons per square inch.

The *soft manganese steel wire*, No. 19 S. W. G., or 0·96 millimetres in diameter (that is an area of 0·00125 square inch), broke at a stress of 124 lbs., with 18 per cent. elongation: the elongation, in fact, was remarkable, being 4 centimetres in 22 centimetres. This breaking stress is equivalent to 48·8 tons per square inch.

The *hard wire* of the same size had a far higher tenacity and far less elongation. The first experiment gave a breaking stress

of 280 lbs., or one-eighth of a ton, which corresponds to the enormous *breaking stress of* 110·2 *tons per square inch.* A second experiment gave a breaking stress of 278 lbs., which corresponds to 109·4 tons per square inch, with an elongation of but little over 1 per cent.; the ordinary steel wire I tried elongated double this amount. Experiments on the breaking strain of bars of this steel have also been made by Mr. Barnaby, the Admiralty inspector in Sheffield, who found that the specimen of manganese steel he tried bore a strain of 67 tons per square inch, with the extraordinary amount of 44 per cent. elongation before breaking.

High as is this figure, the number I obtained for the wire was far higher, and in fact was so remarkably high that I was anxious for an independent determination with another dynamometer. Mr. H. A. Ivatt, the Locomotive Engineer of the Great Southern and Western Railway Works at Inchicore, kindly undertook this for me, as in their works a new and very accurate dynamometer has recently been erected. Mr. Ivatt found my figure was perfectly correct, and sends me the following statement:—

G. S. & W. R.—LOCOMOTIVE DEPARTMENT, INCHICORE WORKS, DUBLIN.

Experiment.	Date.	Description of Material, &c.	Standard Wire Gauge.	Area, sq. inches.	Tensile Stress. Total lbs.	Tensile Stress. Tons per sq. in.	Appearance of Fracture.
1	Dec. 13,	Manganese steel wire, from Prof. Barrett,	No. 19	·00125	291	103·8	Hard and brittle.
2	,,	,, ,,	,,	,,	310	110·7	,, ,,
3	,,	,, ,,	,,	,,	302	107·9	,, ,,

Owing to the extremely brittle nature of the metal, the elongation could not be detected.

(Signed), H. A. IVATT, *Locomotive Engineer.*

Tested by W. C. IRWIN.

Mr. Ivatt also tried a specimen of thicker wire, No. 13 gauge; but I had previously spoilt this specimen by testing the effect of heating it to whiteness and quenching in cold water, which rendered the wire soft. This specimen in its soft state, Mr. Ivatt found, had a breaking stress of 47·4 tons per square inch, nearly

the same as I found for the fine wire in the soft state. Mr. Ivatt tried to harden it, and writes:—"Heating the No. 13 wire to redness, and allowing it to cool very slowly, is, I find, the only way to harden it." This rendered the wire hard and brittle, and apparently lessened its tenacity, for the same wire now broke at a stress of 38·3 tons per square inch.

It will be interesting to compare the tenacity of the manganese steel wire, in grammes per square centimetre, with that of iron and steel. According to Sir W. Thomson (Art. "Elasticity" *Encyc. Brit.*, new edit.), the tenacity or breaking stress of—

Iron wire is, . . .	625 to 651 $\times 10^4$	grammes per	sq. cm.
Steel wire, . . .	859 to 991 $\times 10^4$	,,	,,
Best pianoforte steel wire, .	2362 $\times 10^4$	,,	,,
Common pianoforte steel wire, . .	1851 $\times 10^4$	,,	,,
Hard manganese steel wire,	1735 $\times 10^4$	,,	,,

The two last are my own determinations.

Electric Resistance.—I next determined the *electric conductivity* of the wire. For this I employed No. 19 wire, 0·96 mm. dia., in a length of 510 cm. This had a resistance of 5·22 ohms, *i.e.* practically an ohm per metre. The resistance of the hard and soft wire were exactly alike. The specific resistance was 0·000077 of an ohm, or 77,000 C. G. S. units for a cubic centimetre. This is very high: the sp. resistance of ordinary iron is 9827 C. G. S., and of German silver wire 21,170 C. G. S. units per centimetre cube. Experiments are in progress to determine how far its resistance is affected by change of temperature; but, in any case, the remarkably high resistance of manganese steel wire points to a useful application of this material for the construction of resistance coils for electric lighting and other purposes.

I now come to the next and most interesting feature of this steel—its magnetic inertness.

Magnetic Co-efficients.—Mr. Bottomley, in his note before the British Association, to which I have referred, stated that he had submitted the bar of manganese steel to an enormous magnetising force (far beyond what would be necessary to saturate ordinary steel), and after the magnetisation of the manganese steel he had determined its intensity of magnetisation, by the deflection of a

mirror magnetometer. The number so obtained showed a magnetic moment $\mu = 2{\cdot}55$ C. G. S. units. Dividing this by the weight of the steel we obtain the magnetisation per gramme, which is 0·013 C. G. S. units. Ordinary steel has a number ranging from 40 to 60, and even up to 100, C. G. S. units per gramme.

Hence the ratio of the intensity of magnetisation in manganese steel to that in ordinary steel is as 1 to 3000, up to 1 to 7700 in the best qualities.

So that the intensity of magnetisation that can be given to manganese steel is, say, 5000 times less than that given to steel of average quality; or if steel be 100,000, manganese steel is 20.

This refers to the degree of permanent magnetism that can be imparted. It is important to know the co-efficient of *induced* magnetism of this remarkable body. This co-efficient, designated by K, is the ratio of the intensity of induced magnetisation to the magnetising force of the field, or $K = \frac{i}{H}$: this is now generally termed the *magnetic susceptibility* of the substance.

The experimental determination of this constant, for so feeble a magnetic body as manganese steel, proved a more difficult task than I anticipated, as it is scarcely comparable with iron, and therefore like weighing stones and grains on the same balance.

I first tried the method of torsion adopted by Faraday in the determination of the magnetic force of magnecrystallic bodies, and described by him in the last of his "Experimental Researches in Electricity," *Phil. Trans.*, 1855.

A platinum wire, hung from a graduated torsion head, suspended the specimen under examination in a powerful and uniform magnetic field obtained from a large electro-magnet. A graduated circle was placed below the object under trial, the zero coinciding with the axial position of the object. On exciting the magnet, and then turning the torsion head, the object was twisted out of its axial position, and at last reached a position of unstable equilibrium, when it suddenly swung round to the axial position again, but with reversed ends. The degree of torsion required, *minus* the upsetting angle, was used by Faraday to "measure the force which solicits the body to retain its axial position," that is to say, it is a relative measure of the magnetism induced in the body, or its susceptibility.

A single example out of many experiments will show the working of this method. A piece of manganese steel wire 2·15 millimetres diameter and 44 centimetres long, was suspended (by a platinum wire attached to a torsion head) in a uniform and constant magnetic field. On turning the torsion head, the upsetting angle was found to be 60°, and the torsion required for this was 158°. Hence 158° – 60°, or 98°, is the actual force of torsion employed. With a piece of fine iron wire of precisely the same length and 0·2 millimetres diameter, the upsetting angle was 70°, and the torsion required 320°. Hence 320° – 70°, or 250°, was the force required in this case. The ratio of the forces of the two bodies are therefore as 1 : 2·5. The ratio of the volumes of the two substances will be as the squares of their diameters, or as 1 : 115. Assuming the magnetic moment increases as the volume of the bodies, the ratio of the forces multiplied by the ratio of the volumes will express the ratio of the susceptibilities of the two bodies, which gives

$$1 : 287.$$

There are, however, some objections to this method of experiment, as the upsetting angle is not the same, and hence the magnetic distribution at two different angles will not be alike in the two cases.

The following method is free from this objection. The force required to turn each of the two substances through a given very *small* angle, when they are suspended in a magnetic field of constant strength, is found: this value (less the angle of deviation), multiplied by the ratio of the volumes of the two bodies, will give the number sought. A mirror was attached to the cradle supporting the body, and by means of a lamp and scale, a very accurate measure of the angle through which the substance was turned could be obtained. A constant current of 7½ amperes was used to magnetize the electro-magnet, a uniform field being obtained between two large upright pole pieces. The torsion required to turn the manganese steel through 18° was in one experiment 42°·5, and in another 42°·3, or a mean of 42·4°. The torsion required to turn the fine iron wire through the same angle was 94°. This, less the angle of deviation, gives a ratio of 1 : 3. In a more powerful field the numbers were 66° and 68°, or a mean of 67° for the manganese, and 155°·5 and

156°·5, or a mean of 156° for the iron, a ratio of 1 : 2·8 The volumes of the bodies being as 1 : 115, the former experiment gives a ratio of the susceptibilities as 1 : 345 and the latter as 1 : 322. *Hence we may say that the manganese steel has about* 330 *times less magnetic susceptibility than soft iron;* or, if iron be 100,000, manganese steel will be about 300—a very different number, it will be observed, from that obtained by Mr. Bottomley, for the intensity of permanent magnetisation of the two bodies.

A few experiments were now made to determine whether this method showed that the magnetic moment was directly proportional to the volume of the material. Half-a-dozen pieces of fine manganese steel wire were cut, of equal lengths, and the upsetting force and corresponding angle determined in each case. The angle being 60°, the upsetting forces, less this angle, were as follows :—

	Upsetting Force.	Force per piece.
With 1 piece, ...	132	132
,, 2 pieces, ...	236	118
,, 3 ,, ...	400	133
,, 4 ,, ...	538	134
,, 5 ,, . . .	664	133
,, 6 ,, ...	793	132

Dividing the upsetting force by the number of pieces in each case, we obtain the force per piece, as shown in the last column. With the exception of the second experiment—which is evidently erroneous—it will be seen that the forces are directly proportional to the number of pieces, and hence to the volume of the body.

Since I began this investigation, Dr. J. Hopkinson has sent me his paper on the "Magnetisation of Iron," read before the Royal Society of London, in April, 1885. Until I received this paper I was unaware that Dr. Hopkinson had been experimenting on the magnetic properties of manganese steel. The method adopted by Dr. Hopkinson to determine the magnetic susceptibility was wholly different from that which I employed, and consisted in measuring the induced current generated by the sudden removal of a small coil of wire that encircled the iron or steel bar under experiment, and which bar had previously been submitted to a powerful magnetising current. The maximum magnetisation of

wrought iron and of manganese steel (with 12·36 per cent. of manganese) deduced from Dr. Hopkinson's figures are as 1441 to 5·6, or 258 to 1.

These numbers are fairly in accordance with those I have obtained, viz. 330 to 1, for steel containing 13·75 per cent. of manganese. Considering the wide range of the figures in the table given by Dr. Hopkinson, I should imagine that his ratio is somewhat less reliable than the one I have given.

Other Magnetic Properties.—It was interesting to ascertain whether the presence of this percentage of manganese in steel deprived it of other well-known magnetic properties. As might be expected, it showed no elongation under magnetisation. It did not exhibit the magnetic tick or sound heard when iron, steel, nickel, or cobalt is magnetized and demagnetized. A more interesting question was whether it would exhibit the anomalous expansion and after-glow which take place in iron or steel wire when they cool to a certain critical temperature, after being heated to whiteness. I have shown that these phenomena are coincident with that temperature when the magnetic state of these metals, destroyed by a high temperature, is resumed on cooling. Careful experiments with the manganese steel wire, heated to a bright whiteness, established the fact that no trace of this anomalous deportment on cooling occurred with this substance. Here then we have a singular and an important link between the magnetic state of a body and its sudden and momentary expansion and reheating, when at the critical temperature. Like manganese steel, the non-magnetic metals—platinum, copper, German silver, silver and gold wire—do not exhibit this phenomenon.[1]

I have good hope that the experiments here recorded will become a starting-point for further investigation. When we remember that 13 per cent. of a non-magnetic metal, *mechanically mixed* with iron or steel, produces but a slight change in the magnetic state of the latter, and then consider the profound magnetic change brought about by 13 per cent. of manganese (itself a feebly magnetic metal)

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[1] Nickel, I find, does not exhibit it, contrary to my expectation ; but the magnetic state of nickel is lost at a temperature of 330° to 340° C., which is considerably below red heat. Cobalt wire I have not yet been able to obtain.

when *alloyed* with steel, we are led into speculation as to the nature of magnetism, and why chemical union should destroy the magnetic state. Manganese steel has about the same magnetic susceptibility as ferric oxide; German silver, in like manner, which is an alloy of brass with the magnetic metal nickel, is itself magnetically inert. Why is this? Do the molecules of manganese insulate the imaginary Amperian currents in the iron, and so prevent the molecular movement which invariably accompanies the act of magnetisation? But if so, how? The electric resistance of manganese steel, as a whole, is scarcely 8 times less than iron, but the magnetic power is upwards of 300 times less.

These experiments have also a practical as well as a theoretic interest. From its high tenacity and negative magnetic properties, manganese steel is eminently adapted for the construction of those parts of machines where the magnetic properties of iron or steel are a serious disadvantage—such, for example, as the bed-plates of dynamos.

Moreover, as everyone knows that the deviation of the compass on iron ships is a grave danger in navigation, more especially from the fluctuating character of the sub-permanent magnetism due to the hard iron and steel, the use of manganese steel for the construction of iron vessels and of ironclads in the navy, and for the anchors and chain cables of all vessels, suggests a simple mode of returning to the magnetic safety of our wooden vessels without sacrificing the advantages of iron.[1]

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[1] When the foregoing Paper was read, Mr. Fletcher Moore, of Kilbride Manor, called attention to the fact that a manganese iron ore mine existed at Kilbride, Co. Wicklow, and stated that from this ore iron had been smelted of great tenacity and high quality.

XXXVII.—IRISH MARBLES AND LIMESTONES. By G. H. KINAHAN, M.R.I.A., Etc.

[Read, November 17, 1886.]

CONTENTS.

INTRODUCTION.

It appears expedient to give, as an introduction to the subject of the following pages, an epitome of the geological and lithological relations of these rocks to one another, and subsequently classified lists and sub-lists—those classed as marbles being separated from those more suited for cut-stone purposes: necessarily, however, most of the marbles are also applicable for more general uses.

The lists of the marbles will be as complete as possible, and in them will be included all places where stones have been worked as marble, whether successfully or otherwise. To these will be added other places in which stones are found that may possibly be hereafter utilized.

Marbles proper are limestones or metamorphosed limestones of a nature capable of taking and retaining a good polish. The metamorphosed limestones belong to two divisions—those that have undergone simple metamorphism, that is, have only been altered by the action that affected the associated rocks; and those that underwent a second or after change, due to chemical action from without (*methylosis*). These secondarily changed limestones, including dolomytes (*ophiolytes*, *ophicalcytes*, *dolomytes*, &c.), are generally called Serpentine; but under this general name are also included chemically-allied rocks (*ophytes*, *eklogytes*, *steatytes*, *pyrophyllytes*, &c.), rocks that originally were in general of volcanic origin. It therefore is expedient to include these also under the title of marble, and class them all together, not only on account of their chemical relations, but because all are generally recognised as marbles; and, if separated, would lead to confusion. As they will be hereafter given in separate sub-lists, and their proper relations to one another be pointed out, there will be no incorrect scientific classification.

The marbles will be classified as much as possible according to colour, under the county names, placed alphabetically; while, at the same time, their geological and lithological positions will be kept separate, and each will be described so as to give a general knowledge of the rocks, and the probability of their being of economical value.

The list of the limestone quarries will not be so full, as it would be unnecessary and undesirable to mention all quarries; the nature of the proposed list being to point out as many places as possible where good stones, suited for cut-stone purposes, can be obtained, or stones that, from some specialty, are eminently suited to be used in the construction of piers, harbours, or such-like massive works. These lists will be complete, as far as possible: but some isolated quarries, locally, though not generally, known, may be omitted. At the end of each county list is given the general nature of the lime, and other purposes are mentioned to which the stone has been applied. In the counties where limestone is scarce, all localities in which it is found are given, whether they are suitable for cut-stone purposes or not.

The geological grouping adopted is the same as that given in the Table of Geological Strata in the Paper "On Irish Metal Mining" (*ante* p. 204).

Some of the recent limestones accumulating at the present time might be utilised in the manufacture of articles of *vertu*. They scarcely, however, come within the scope of this Paper, although it would be incomplete without a reference to them. Such are the stalactytes and stalagmytes of the caves, and the massive tufas accumulating in the vicinity of some of the calcareous springs.

Next before these in geological order is the Cretaceous or White Limestone, of a similar age to the English Chalk, but possessing, on account of its induration, a distinct character of its own. This stone is principally quarried to burn into lime, as it is not suited for fine tool-work, being full of concealed cracks and irregular joints. It can, however, be scabbled into stones of small dimension, very suitable for rough masonry. In some places it is ground up, and manufactured into whiting.

The limestones belonging to the Lias are of little note, being only nodules and layers of small dimensions, and apparently of little value, as all attempts to convert them profitably into a cement have, up to the present, failed.

In the Trias there are, in a few localities, massed and lenticular beds of gypsum.

In the Permian beds, the only known calcareous rocks are dolomytes. They are so rare, that they have been little utilized,

except some near Belfast, which were formerly exported to Scotland for the manufacture of sulphate of magnesia.

In Ireland, the great development of limestone was in the Carboniferous Period. These rocks occupy nearly the whole of the central plain, with ramifications from it, and in some places they exist in tracts that are more or less isolated and of variable extent. In these the characters of the rocks differ greatly, some being nearly pure limestone, while others are argillaceous or arenaceous, often to such an extent as to almost lack the calcareous constituent.

For convenience of description, the Irish Carboniferous Limestones may be subdivided as follows :—

I. The earthy crystalline, or *Lower-Bedded Limestone.* These rocks are more or less common at the margins of the tracts of the different types of limestone ; they are bedded, and in general have shales or clayey partings between the beds, and are often capable of being raised in large masses, but rarely are they eminently suited for cut-stone purposes. As large blocks, they are valuable in the building of piers, foundations, or other massive works.

II. Amorphous or *Fenestella Limestone.* The latter name has been suggested by Wynne, as the mass of the rock in general is made up of this Corralline. The rock originally seems to have been coral reefs, any bedded portions in it being for the most part above or below, or as isolated subordinate parts in the mass. This rock, in general, is not suited for cut-stone purposes, although some of the included portions, when manufactured, afford beautiful marbles. At the present time, except some few beds, none of the rocks of this type seem to be in much favour with the marble-workers ; yet from them our ancestors were able to produce exquisite specimens of art. The work cut from stones of this class in the Geraldine banqueting hall at Askeaton, Co. Limerick, and that, in the chaste and beautiful pillars of the cloisters in the adjoining abbey, cannot be surpassed.

III. *Calp*, or earthy compact limestone. These rocks are, in general, not good for cut-stone purposes; but they can usually be raised in large blocks, for which reason they are valuable for massive works. Some beds, however, are very compact, homogeneous, and capable of taking a fine polish, and, under such circumstances, have produced first-class marbles.

IV. *Burren type.* The limestone of this class was so called by Foot on account of its being best developed in the barony of Burren, Co. Clare. These rocks, when typical, are in shades of grey and blue, being crystalline, but compact and free-working; while many beds are suitable for all kinds of cut-stone work. All the chief Irish quarries of the present day are situated in the limestone of this type, and in ancient times all fine workmanship, with rare exceptions, such as the work at Askeaton, was executed in stone of this class. It might naturally be expected that the principal black marbles should be found in the Calp: this, however, seems not to be the case, as some of the world-famed Irish black marbles are from subordinate beds in the limestone of the "Burren type." This, to us, appears to have led to a misconception, as some of the tracts classed on the geological maps as "Calp" are so called solely from their having in them beds of black marble, while, correctly speaking, they should be mapped as "Burren limestone."

It is necessary to explain that the above classification is solely a lithological one, the rocks being arranged according to their general characters, and not to their geological position. The ordinary geological classification has been found, even by those who still use it, to be unstable, as the rock-characters, at first adopted as conclusive of age, being now found to vary according to the circumstances under which the rocks accumulated; purer limestones accumulating in deep water, while littoral and shallow water depositions had peculiar and special characteristics. The rocks of class I. were evidently littoral accumulations; those of class II., the growth of coral reefs or such like; those of class III., accumulations in greater or lesser expanses of shallow, still water, into which fine silt or mud was drifting; while the nature of the accumulations of the rocks of the Burren type is hard to determine, as at the present day there do not appear to be any records of exactly similar depositions.

We have adopted as much as possible the recognised names—a plan which may be, in part, unsuitable to pure geology; but, at the same time, as the geologists of the present day, in respect to Europe in general, and also more or less elsewhere, are colouring their maps, rather in accordance with lithology than geology, it seems allowable for us to adopt the names that are best known and

that will be most intelligible, especially when the correct definitions of the names are also given.

Other Carboniferous limestones are those that occur as the basal beds of the Carboniferous rocks, associated with the conglomerates, in the counties of Clare, Galway, and Tipperary. These, however, are of minor importance, and appear to have been but little utilized.

There are also limestones that occur at the margin of the Ordovician (?) or Cambrian (?) metamorphic rocks to the northward of Castlebar, Co. Mayo, which Symes suggests are of Carboniferous age (*Geol. Surv. Mem.*). His arguments cannot be lightly passed over; the principal ones being that these limestone are unconformable to the associated rocks, that they occur in more or less dyke-like masses, and that they are devoid of the characters of metamorphic limestone. An examination of the rocks seems to prove that they must be much more recent than the adjacent metamorphic rock, and that they are of Silurian or Carboniferous, or even of a later age. Symes, after his examination, suggested that they were Carboniferous, and due to the filling in of open fissures, during that period, with Carbonifereus matter. It is, however, possible, as has been suggested by myself, that these fissures were filled in by Silurian limestone. To this we shall refer presently. All these limestones are more or less used for lime, some of them being hydraulic.

In the Silurian group (*which includes the rocks that have been called Upper Silurian and Lower Old Red Sandstone*) limestones are rare, and occur in beds of small dimension. They have been recorded in the following places:—At Croaghmartin, in the Dingle promontory, Co. Kerry, are some insignificant arenaceous limestones. In the Co. Galway, at Salrock, Derreennasliggaun, and Leenaun, there are small subordinate masses of limestone, those at Derreennasliggaun being in part somewhat coloured red. Farther eastward, partly in the counties Galway and Mayo, are peculiar limestones, associated with the eruptive rocks that occur at the base of the Toormakeady conglomerate. These rocks are very interesting, as they may possibly be of the same age as the limestone northward of Castlebar, which, as suggested in the previous paragraph, may be either Carboniferous or Silurian. South-eastward of Louisburgh, in S. W. Mayo, there are thin limestones, in

part schistose (*metamorphic*). In N. E. Mayo, between Charlestown and Ballaghaderreen, in two places, there are beds of impure limestone; and in the Co. Tyrone, between Sixmile-cross and Pomeroy, there are three or four beds of limestone. These Silurian limestones have been utilized for lime, especially those in South Mayo and Tyrone. Hydraulic limestones occur near Tourmakeady.

Limestones in the Ordovicians (*Cambro or Lower Silurians*) are not very uncommon, having been recorded in the Cos. Wicklow, Wexford, Waterford, Galway, Mayo, Sligo, Donegal, Londonderry, and Tyrone. All are more or less schistose (*metamorphic*), and usually are not suitable for cut-stone purposes; there are, however, some stones in the Co. Donegal, that appear to belong to this group, which have produced excellent work. All these limestones are more or less utilized for lime, some of them being hydraulic.

Limestones of Cambrian age are found in Galway, and probably in Donegal. There are also limestones in the Cos. Londonderry, Tyrone, Sligo, and Mayo, in rocks that may be metamorphosed Cambrians; but the age of these rocks has not been satisfactorily determined. These are all more or less metamorphosed, some also being chemically changed into Serpentine. They are not in general good for cut-stone purposes, but beds both in Galway and Donegal have been worked, and found to dress well; while some have also been worked as marble. The green and variegated Serpentines of West Galway have been worked for marble, and are well known in the market. The more general purpose for which the Cambrian limestones are quarried is the manufacture of lime.

Lime.—As a general rule Irish limestones are suitable for the production of lime, some of them being eminently so. The principal exceptions are found in the Calp, some beds in which are so arenaceous, or argillaceous, that they are rather sandstones, or shales, than limestones. Some of these will not burn at all; others only with great care.

The richest limes are produced by the White and Fenestella limestones, some, indeed, being too rich for sound building purposes, unless they are properly mixed with clay and sand. The limes are almost invariably of a good white colour.

The major portion of the other limestones, as a rule, give more or less dark-coloured limes; while some from the metamorphic limestones, especially those of Ulster, are so dark as to appear more like brick-dust than lime; in general, however, they are good strong limes. Most of those from the rocks of Carboniferous age give a good return, but the returns from the Metamorphic rocks are usually below the average.

The strength and durability of lime made from some of these limestones are shown in ancient, and even modern structures. In various places, in the ruins of the ancient castles and other buildings, it can be seen that as the buildings came to be demolished, the mortar proved stronger than the stone. This is well exemplified in the old castle in the Flats of the Shannon, near Clonmacnoise, which was built on an artificial clay mound. When the Shannon cut away the clay foundation the castle fell in masses, the weight of the latter breaking through the stones, while the mortar remained unbroken. The Round Tower, Kilmacduagh, Co. Galway, leans over considerably out of the perpendicular, and has not given way, although some years ago it was struck by lightning, and cracked at the top. A modern example of good work was the garden wall at Cowper's Hill, Queen's Co., built some hundred years ago. This had to be removed, but as both the bricks and mortar were of such excellent qualities, that the wall could not be pulled down without great expense and labour, it was cut into junks, and moved to its new site.

As stated, in some places the limestones are hydraulic. These were used in various waterworks, constructed some years ago, the localities for the different stones being then known; a list was drawn up some thirty years ago by Griffith, but it was never published, and now it seems to be lost.[1]

The localities at present known for hydraulic limestones will be given in their respective counties; but these will not embrace all that really exist, as the published records are scant.

The natural cements are not of the same value now as they were formerly; for, as Wilkinson and General H. Y. D. Scott, R. E.

[1] The late Mr. John Byron informed us it was, he believed, destroyed by Griffith, who considered it useless, as "natural cements" (made from hydraulic limestone) had been superseded by artificial cements.

(*Proc. Inst. Irish C. E.*, May, 1880), have pointed out, they give uncertain results, one portion of a bed, or accumulation, being so different from those adjoining. This has in a great measure led to the general use of artificial cements, which can be made of a uniform quality and strength. Consequently, the Irish hydraulic limestones have been for years almost entirely ignored.

Scott and others have shown that cement can be manufactured from any limestone if the proper constituents be added. This, however, requires considerable skill in manipulation, which is only to be acquired in time by careful observation on the part of the workers while making the cement. The great art in making cement consists in getting materials that can be easily and cheaply associated, so as at the same time to produce a good article. Various attempts have been made in Ireland, and although as good as that imported, if not better, has been made, yet the results pecuniarily have not been very satisfactory.

There are, however, some clays in Ireland that might possibly give good results. Near Ballynamona, west of Cong, Co. Galway, there is a clay that was successfully used in the manufacture of cement for the waterworks at Ashford, Cong (*Geol. Surv. Mem.*). Again, the violet-coloured lithomarge found in the "Iron Measures," Co. Antrim, seems to have qualities identical with those of the Pozzuolana of the Bay of Naples. It has not, however, yet been experimented on. There are the muds of some of the estuaries which ought to contain the ingredients necessary for cement, if lime were added to them, or, perhaps, in some cases even without the latter. These also, however, have not as yet been tried, except some in the estuary of the Slaney, Co. Wexford, which are now being employed in the manufacture of a first-class cement at Drinagh, south of Wexford.

Plaster of Paris.—In connexion with the rocks of Triassic age, no limestones, except the supposed Permian dolomytes,[1] have been found, but in some places there are accumulations and beds of gypsum. At Derrynasrobe and Knocknacran, near Carrickmacross, Co. Monaghan, there is a thick accumulation, which has been proved for a depth of 60 feet. Plaster of Paris was manufactured in this

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[1] The dolomyte, with Permian fossils, at the Annaghone Colliery, Co. Tyrone, occurs in intimate connexion with the Trias.

neighbourhood, but the works were accidentally burnt down a few years prior to 1870, and since then the manufacture has not been resumed. Gypsum has been found associated with salt near Carrickfergus; also in the valley of the Lagan, Co. Antrim. Dr. Ruttey, in his *Natural History of Dublin*, mentions it as occurring at Multikartan, near Lisburn, and it has also been found at Coagh, Co. Tyrone.

The variety called alabaster, suitable for architectural and ornamental purposes, is not recorded as having been found.

MARBLES.

The Irish marbles are not only very varied, but some of them are handsome, and even beautiful. They occur among the Carboniferous limestone and the Metamorphic rocks, the latter being of Ordovician and Cambrian ages. For the most part they are limestone; but some are more or less chemically changed, and are known under the general name of Serpentine. The latter name, however, not only includes the altered limestones and dolomytes, but also certain altered volcanic rocks. The metamorphosed limestones and allied rocks will be more specially mentioned hereafter.

CARBONIFEROUS.

The limestones of Carboniferous age capable of being worked as marble occur in various shades of red, black, grey, and other colours. The red varieties of limestones are rarely of one uniform colour, being usually more or less clouded or variegated. Some of these are beautifully and fantastically marked in lines or clouded tints of grey, white, purple, green, and yellow, and deserve to be much more generally known than they are at present. Some of the black limestones are world-famed, and cannot be surpassed for blackness, or for the beauty of the stone; while others are more or less mottled or spotted with white, generally owing to the presence of fossils. The grey tints graduate from dark to almost white, being often more or less clouded with darker shades, and also with purple, changing them into dove-colour.

RED and VARIEGATED MARBLES.

[RED and VARIEGATED stones are recorded, and have been worked more or less in the Cos. of Armagh, Clare, Cork, Dublin, Kerry, Kildare, Limerick, Longford, and Tipperary, those that have been principally worked occurring in the Cos. Armagh, Cork, and Limerick.]

ARMAGH.

The marble quarry at Armagh was at one time very extensively worked both for building stones and marble. In the principal bed the colour was a pinkish-grey, which, when polished, was of a warm yellow colour. From this bed large blocks suitable for columns were procured; and associated with it were reddish beds, alternating with whitish. These were quarried for the purpose of being wrought into chimney-pieces and other ornamental work. The rocks formerly raised seem to have been better than those at present obtained; or else tastes may have changed, as now the rocks are considered light in colour and unsatisfactory, and their place has been taken by the Cork and Belgian "reds."

At the present time (*Geol. Sur. Mem.*) there are four separate series of marble—(1) Uppermost are ten feet in thickness of variegated bluish-red stone, in beds from one to three feet thick; (2) A little below these is the *white marble*, a pale, crystalline rock, forming a bed three feet thick; (3) Two feet under the latter is the *shell marble*, a fossiliferous bed, of about one foot in thickness, of a purplish-brown colour, variegated with green and yellow, while nine inches lower is—(4) the *thrush marble*, consisting of ten feet in thickness of a mottled-purplish rock, marked somewhat like the breast of a thrush.

CLARE.

To the south of the Co. Clare, a little east of the Fergus between Newmarket and the Shannon, there are beds in the Fenestella limestone which have been worked as marble, and were used for ornamental purposes in Adare Manor, Co. Limerick, and elsewhere. The stones are red, red clouded with grey, and grey clouded with red. They do not rise in well-shaped blocks, but good-sized stones may be raised which can be scabbled into blocks of fair dimensions.

CORK.

The best Irish "reds" in the market at the present time are procured in this county. They have been worked at Boreenmanagh, Churchtown, and Little Island, near Cork; Johnstown near Fermoy, Midleton, and near Buttevant. These marbles are well known, and have been extensively used. They vary in colour, from a red, like jasper, to streaked and variegated. All except those at Boreenmanagh, Johnstown, and Midleton, are of one type, known in the market as "Cork reds." At Midleton the stone varies from a warm dove-colour to a rich variegated marble, while those at Boreenmanagh and Johnstown are semi-transparent, mottled, or clouded with white and grey.

These stones have been used in the following instances, among others:—The Little Island "red," in the Liverpool Exchange, the Manchester Exchange; Museum, Oxford; St. John's College Cambridge, &c. The Fermoy "red," in the Cathedral, Queenstown; Roman Catholic Church, Thomas-street, Dublin, &c.

The Midleton stone has only lately been known, but it has rapidly taken a place. It is more properly a clouded grey than a true red. It has been used, among other places, in the Manchester Exchange; St. Mary's Church, Bradford, &c.

Cork "reds" have also been used in the Town Hall, Rochdale; Miss Bottomley's, Bradford; St. Mary's, Abbots, Kensington; St. Pancras Hotel and Station, &c.

DUBLIN.

In this county, at Johnstown, there is a red stone which was tried, but it seems not to have been much approved of, and has now ceased to be spoken of.

KERRY.

Near Killarney there is a striped red-and-white stone which has been worked a little, but unsatisfactorily. In other places in the county there are reddish and pinkish stones on which trials have been made, but as yet no good profitable stone has been found.

Kildare.

At Celbridge is a stone recorded by Sir R. Kane, but it does not appear to have been worked to any extent, and its existence is generally now ignored.

Limerick.

Red marbles ("reds") have been more worked in this county than in any other except the Co. Cork. This may possibly be due to the action of the late Earl of Dunraven, who, during the erection of Adare Manor, seems to have searched the counties Limerick and Clare for "reds," specimens of which can be seen in different portions of the edifice, some having been used in outside work, while most of them are represented in the chimney-pieces and in ornamental slabs used for decoration.

In general the "Limerick reds" are clear-coloured, varying from shady or coloured red to variegated, with grey, green, yellow and other tinges; this, however, is not the case in the Pallaskenry rock, which is of the type known as the "Cork reds." This rock was extensively used by Lord Clarina when building his new mansion, and by Lord Dunraven at Adare Manor.

At Clorhane, two and a-half miles north of Adare, half a mile west of Stone Hall, immediately west and north-west of the old church, also half a mile to the west, and half a mile to the south-west of the new church, are quarries which were open and worked during the erection of Adare Manor. In these places, except at Clorhane, the works were of small extent, only a few blocks being removed to be worked into slabs for chimney-pieces. At Clorhane, however, all the "red" was taken away, but some years afterwards the grey stone below began to assume the red colour.

Other places in this county, in which red rocks are recorded, are, a little east of the ruins of the ancient church, to the N. E. of Clorhane Bridge, and in the railway cutting south of Askeaton, a pinkish-greyish stone, in places yellowish, was used for the beautiful pillars of the cloisters of Askeaton Abbey, built by the Earls of Desmond (Geraldines) in the fourteenth or fifteenth century. The exact places where this stone was procured is now unknown, but it evidently came from some place in the neighbourhood.

LONGFORD.

Near Ballymahon, brown red and mottled-grey stones were formerly worked (*Kane*).

TIPPERARY.

Near Dunkerrin are recorded stones of red to purplish colour, veined with yellow (*Kane*); but no extensive works seem to have been carried on. Different marbles appear to have been sought after in this county during the time the marble works at Killaloe were in full work.

BLACK MARBLES.

[*Black Marbles* have been worked, or have been found, in the Cos. Carlow, Donegal (?), Fermanagh, Galway, Kerry, Kilkenny, Limerick, Mayo, Monaghan, Sligo, Tipperary, and Waterford.]

The black marbles of Kilkenny are historic. Although we have in very ancient structures, such as those of Askeaton, Co. Limerick, and Clonmacnoise, King's County, examples of very ancient marble, yet the first written record of Irish marbles seems to be that of Gerrard Boate, written in 1652.

The Irish black marbles were at one time in great request, quarries in various counties being worked in a great measure for exportation to England and elsewhere. The black varieties were principally in demand, but also the black speckled or marked with white. The pure black marbles were chiefly required for monumental purposes, but not always, as a considerable quantity of the Angliham stone, Co. Galway, was exported to London for the Duke of Hamilton's staircase, in his mansion in Scotland. Although in later years the best "blacks" were most in requisition, yet the black mottled or spotted with white, like the famous Kilkenny marble, which got the Irish marbles a name, were much sought after; and also inferior "blacks," the latter being required for local trade in tombstones and such like. Now the trade in "blacks" is very low, none but the best, which have an extensive sale, being much looked for. The black-and-white are not now in much requisition; while the fashion in tombstones of late years has so changed, that inferior "blacks" have now no place in the general market. For these reasons, combined with the gradual depression

in trade, only a few out of the great number of quarries at one time in work are now profitable. The best "blacks" only will be received in the London market: formerly there was a competition for them between it and the American market.

Carlow.

In the town of Carlow two quarries were formerly worked, one at Montgomery-street, and the other in the townland of Crossnear, the latter being in the suburb called Graigue, west of the river Barrow, in the Queen's County. In the Montgomery-street quarry there were four beds, 7 inches, 2 feet, 3 feet, and 18 inches thick, the thin beds giving the best marble. In the Graigue quarry there was 5 feet in thickness of a stone, that was worked for tombstones, and sent to the Dublin and Waterford markets; and under it were nearly 2 feet of superior black stone. In the Carlow quarry, the limestone over the 18-inch bed could also be used for work of a similar nature. Carlow was once famous for its tombstones, and at the present time the trade is still carried on, very creditable work being sent out from the stonecutters' yards; but it has sadly fallen off from what it once was; this being, in a great measure, due to the fact that sandstone monuments are now most in requisition.

Royal Oaks.—A little more than a mile west of Bagnalstown there is a large quarry, in which marble was procured; and a second further north, nearly a mile south-west of Killinane House. In both these places stones for black marble were, in time past, extensively worked, some being fit for the London trade.

Ballynabrannagh, northward of Milford.—A good black marble was formerly procured in this quarry.

Clogrenan.—There is here a quarry in limestone, immediately under the coal-measures. One bed is a good black, partly spotted with white. It has not been very extensively used. The columns in the hall at Clogrenan House were cut out of this stone.

Donegal.

As mentioned by Kane, in his *Industrial Resources of Ireland*, there is in *Kintale*, to the north of Rathmullen, a black bed of imestone that has been worked as a marble. It, however, is of such small dimensions as not to be of commercial value.

FERMANAGH.

Carrickreagh, five miles from Enniskillen.—Not a very good black, but takes a good polish; has been used greatly for tombstones. At various other places there are blackish stones, that have been locally used, but none of those known are of good or even fair quality as black marbles.

GALWAY.

The premier black limestones are now supplied from this county.

Angliham and Menlough.—The marbles from these quarries, which are situated three miles north of Galway, are world-famed, and include some of the best, if not the best, examples of black marble ever known. These were at one time extensively exported to London and America, the stone from one bed being all kept for the London market, from which it has received the name of the *London bed.* Wilkinson, when writing of these quarries in 1845, pointed out that, on account of the eastern dip of the strata, the head over the marble beds was gradually increasing, while the floor of the quarry was becoming of an inconvenient depth below Lough Corrib, both of which circumstances were gradually adding greatly to expenses incurred in removing the superfluous stone, and in keeping the quarry dry. In 1868 there were 40 feet of clearing over the marble beds. At that time, in the Menlough quarry, there were two good beds, one 13 and the other 15 inches thick, below flaggy beds, used for tombstones. At the same time, in the Angliham quarry there were three beds, the *Thin,* 9 inches thick; the *London,* 12 inches; and the *Double,* 14 inches. The Thin bed was the purest marble, while the 12-inch got its name from being kept solely for the London market, preference being given to it on account of its capability of being cut most economically. The principal markets were London, Liverpool, Bristol, and Glasgow. At the present time the clearing and pumping have greatly increased, which adds much to the cost of getting the stone.

Merlin Park. About two miles S. E. of Galway.—In this quarry two sets of beds were formerly extensively worked by the

Blakes of Merlin Park, till about the year 1850, after which it lay idle till within the last few years, when it came into the hands of the Messrs. Sibthorpes of Dublin, who have since worked it, the stone being very good, equal to the stone from the Angliham quarry. Quite recently, on sinking below the floor of the old quarry, other black beds have been found, which appear to be of superior quality; but as yet very little can be said about them, as the surface has still to be cleared off. In the quarry there is a clearing of about 25 feet of rock, the upper 17 feet being loose. Under this are three beds of marble, 6, 11, and 15 inches, the two lower sometimes forming one, about 2 feet 2 inches thick. Below the upper marble are about 10 feet of black limestone that lie on three marble beds, 12, 15, and 12 inches thick, while still lower are the new beds.

In *Gortveragh*, north of the Glebe-house, and a mile E. S. E. of Oughterard, there is a fair black stone that was formerly worked by the Martins of Ballynahinch. It can be raised in very large blocks, but at the present time the stone is not favourably received. The old scabbled blocks still lie there, the quarry not having been worked since the Martins' time.

Creggs.—Between the last place and Oughterard there is a bed of black marble, spotted with white, which has not been used except very locally. It is capable of being raised in large sizes, and of taking a good polish. A slab 10 feet by over 5 feet was used for the landing at Lemonfield hall-door.

Kerry.

Good marbles were formerly obtained at *Ballinageragh*, five miles west of Listowel, and also near Tralee. In recent years trials have been made in these places, and elsewhere, but none of the stones were considered suitable for the present demand. The Kerry stone in general is more or less spotted with white, some of it being variegated.

Kilkenny.

Near Archer's Grove, and about half a mile south-east of the town, is the historical *Black Quarry*, with which has been connected the name of Colles for the better part of two centuries. Dr. Gerrard Boate, writing in 1652, mentions :—"Besides the freestones

which is in every part of the land, there is marble found in many places, but more about Kilkenny, where not only many houses are built of the same, but whole streets are paved with it. The quarry out of which they have their marble at Kilkenny is not above a quarter of a mile from the town, and belongeth to nobody in particular, lying in common for all the townsmen, who at any time may fetch as much out of it as seemeth good unto them without paying anything for it. . . . . This marble, while it is rude as it cometh out of the ground, looketh greyish, but being polished, it getteth a fine brownish colour, drawing somewhat toward the black."

Boate does not appear to be quite correct in saying it was free, as it would appear to have been for years the subject of a suit in Chancery, between the families of Jacob and Minchin, from both of whom Alderman William Colles took leases in 1737, having a few years previously (about 1730) invented machinery, worked by water-power, for cutting, polishing, and boring the marble; and since that time his descendants have had the sole use of it. Alderman Colles' works are mentioned in a *Tour in Ireland*, by two English gentlemen, A. D. 1748, and in Tighe's *Statistical Survey of Kilkenny*, published 1802; while we learn from a recent inquiry instituted by Professor Henry, M. Seely, Middleburg, Vt. U. S. A., and published by the Middleburg Historical Society, that Colles was the first to apply water power for the polishing and boring of marble, using it for cutting being in part a re-invention, as in the fourth century of the Christian era stones had been sawn by water-power on the river Roen in Germany.

The Kilkenny marble quarry proper, the "Black Quarry," is close to the river, near Archer's Grove, and about half a mile S. E. of the town; this is supposed to be the quarry mentioned by Boate, and has been worked for at least a century and a-half by the Colleses, the great-great-grandfather of the present proprietor having been the founder of the Kilkenny marble works for the manufacture of chimney-pieces, picture frames, tables, and various other articles, by water-power.

In this quarry there are three varieties: *shelly black*, *pure black*, and *dark-grey*. The shelly black is *par excellence* "Kilkenny marble," the black, with white shells, being world-famed under that name; and in connexion with it was the curious general belief, that the stones when first procured are perfectly black, the

white shells appearing subsequently, being gradually developed when the marble is subjected to heat. But Mr. Colles states this is a fallacy, as he has never known a case in which this occurred, and the fossils are always to be seen from the first.

The pure black is hard and fine-grained, and makes good slabs, a very fine one being in O'Connell's tomb, Glasnevin, Dublin.

At Sion Hill, opposite, on the east of the river Nore, marble was formerly raised, but not of as good a quality as in the Black Quarry, and has not been worked for thirty or forty years, the quarry being now closed up.

At Butler's Grove, near Monefelim, north-north-west of Gore's Bridge, there is a very pure black marble, which at the present time is worked at the Kilkenny works, while formerly it was in great request.

West of Thomastown is a black stone, but not of good quality; it was, however, formerly much used for tombstones, the heavy clearing over it being burnt into lime on the spot, and sold for farming purposes; but since the demand for lime fell off the quarries, like many others, are nearly idle.

Limerick.

Good "blacks" were also formerly procured in this county, they being wrought in the quarries, and at the Marble Works, Killaloe, on the Shannon, while the best were exported to London. There appears to have been beds of different qualities, the most valuable being those which were of even texture and free from silex, as the presence of the latter not only made them hard and costly to work, but also less capable of receiving a polish.

At Thomond's Gate, Limerick, a quarry was formerly largely worked, the famous "Broken Treaty Stone" being a rough block from it. Under the present railway station there was a large quarry, the lowest bed being an excellent black stone fit for the London market, and which was worked up to about the year 1830. Over two miles from Limerick, at Ballysimon, there were stones of excellent quality, some of the best of which were sent to London. The beds varied from 7 inches to 4 feet, and 6 feet in thickness, the premier bed being one 12 inches thick.

Black marble was also procured at Banks' quarry and Carey's-road; and when the railway was being made from Limerick to Foynes, black marbles were cut at about half-way between St. Patrick's Well and Adare; also near the margin of the marsh between Adare and Rathkeale.

MAYO.

In Partry there is a superior stone, but in so small a quantity that it does not appear worth quarrying. There is also a fair stone near Castlebar, which at present has only been partially tri ed.

MONAGHAN.

There is a fair black stone, near Glasslough, which appears to have been locally used, but which is not generally known.

SLIGO.

In this county black stones, capable of receiving a fair, good polish, have been procured in different places, but they appear to have been principally utilized for tombstones.

TIPPERARY.

Near Dunkerrin, near Portumna Bridge, and at Castle Briggs, on the Shannon, beds of marble were formerly worked. Stones from the second and third localities were sent by water to the Killaloe Marble Works, but they are not now worked.

WATERFORD.

Black marbles, which were locally used, are said to have been procured at places in the limestones between Lismore and Dungarvan.

GREY MARBLES.

[*Grey marbles* are recorded from the following counties:—Armagh, Carlow, Cork, Galway, Kerry, Kilkenny, King's Co., Limerick, Longford, Tipperary, Waterford, and Westmeath. They might be procured in different other places if there was a demand for them, but only those with peculiarities are much sought after. Many of the so-called reds are more properly clouded greys.]

Armagh.

In the famous quarry for "reds," the so-called "white marble" is a very light, whitish grey.

Carlow.

In the Clogrenan quarry there is a crinoidal, fossiliferous stone, somewhat like the famed Clonmacnoise stone, in the King's County.

Cork.

The stone at Midleton, although in general classed as one of the "reds," is more properly a variegated or clouded grey.

Galway.

At Angliham, three miles north of Galway, one of the beds worked in the "Black Marble Quarry" is a dark-grey. Near Angliham, in Terrylaw, to the N. N. W. of Mr. Carter's house, there is a handsome grey spotted and speckled stone. This has not been worked as a marble, but a polished specimen is in the Museum, Queen's College, Galway.

About three miles from Ballinasloe is a superior dark-grey stone, capable of being raised in very large blocks and of receiving a fine polish. It was extensively used in Lady Burdett Coutts' markets, London, at East Grinstead, Covent, Chester, &c.

Various grey stones of the Burren type, in other places in this county, are suitable for marble, if there was a demand for "greys."

Kerry.

In this county trials have been made on "greys," which have been found very good; but on account of their distances from the market, and from the fact that stones of this colour are not much in request, they have not been utilized, except locally. In colour they vary from a clouded light tint, or nearly white, to dark and blackish.

KILKENNY.

One of the beds worked in the "Black Quarry," Kilkenny, is a dark grey. In the Ballykilaboy quarry, about four miles from Waterford, there is a superior stone, capable of being raised in very large blocks, 17 feet by 5 feet, and 2 feet thick.

KING'S COUNTY.

At the Ballyduff quarry, near Tullamore, there is a very superior stone, of grey colour, graduating into a wan dove-colour. This has been very extensively used in the locality for chimney-pieces and ornamental slabs. It is a beautifully clouded stone in places, and seems well worthy of more public notice than it has as yet received.

Near the Seven Churches, Clonmacnoise, are the well known fossiliferous crinoidal mottled-grey stones, formerly most extensively worked at the Killaloe Marble Works, to which they were brought by water, and still very much used on account of their peculiar appearance.

LIMERICK.

In this county, associated with the "reds," already enumerated, there are "greys," except at Pallaskenry. Some of these reds are in part clouded, or spotted grey, or graduate into grey or dove-colour. The beautiful stone used in the cloisters at Askeaton is, in general, a grey, some parts only being clouded with red or other colours.

LONGFORD.

At Ballymahon a stone has been raised which, when polished, is grey, mottled with red and brown (*Kane*).

TIPPERARY.

Near Dunkerrin there were various trials made for marble. One stone reported, was pale-grey nearly white; and a second a purplish-grey, or dove-colour (*Kane*).

Waterford.

In the crags between Lismore and Dungarvan there is a light-grey, nearly-white stone, capable of receiving a good polish; it is said to have been procured and locally used (*Kane*).

Westmeath.

At Hall, three miles S. W. of Moate, there is a very good quality of grey stone, splashed with white. In some there are red veins, but this variety is not as sound. It was used extensively at the New Exchange, Manchester, in Bradford, and other places in England.

VARIOUS-COLOURED.

[Various-coloured marbles of Carboniferous age, which cannot be classed with the "reds," "blacks," or "greys," are recorded from Clare, Donegal, Fermanagh, King's Co., and Tipperary.]

Clare.

At Clondes Lough there is a fine bardilla, or bardiglio marble (*Kane*), a bluish-grey stone, with irregular fine lines and blotches of a dark colour, called originally from Bardiglio, in Italy, where it principally comes from, as pointed out by *Colles*.

Donegal.

In Glendowan, westward of Lough Veagh, there is a ribanded Sienna-coloured stone, but so thin-bedded as to be valueless as a marble. It, however, takes a good polish.

Fermanagh.

In a hill between Castle Caldwell and Belleek is a pale-grey crinoidal limestone, with red spots and circles, due to scattered crinoid stems that are stained with iron. A pillar of it is in the Museum of Trinity College, Dublin.

KING'S CO.

Near Clonmacnoise, *Wilkinson* records "a beautiful marble of Sienna character." It is easily worked, and has been frequently used for ornamental works, and "deserves to be more generally known than it at present is." This stone, although of Sienna character, is not of Sienna colour, it being more of a purplish-clouded grey.

TIPPERARY.

Among the marbles mentioned by *Kane* as occurring near Dunkerron are some of yellow colour, and veined.

METAMORPHIC ROCKS.

The rocks next to be enumerated are probably metamorphosed Ordovicians (*Cambro or Lower Silurians*) or Cambrians, generally the latter.

These marble-bearing stones must be subdivided, as one class was originally limestone or dolomyte, while the other was volcanic rock, *exotic rock*, or those allied to them. The latter have to be included, because, as previously pointed out, they, and also certain peculiarly altered limestones and dolomytes, are generally classed together under the common name of *Serpentine*, both the limestone and volcanic rocks having undergone a secondary change, due to a chemical action from without, which has been called by Dr. King, of Galway, *Methylosis*. The limestones that have only undergone simple metamorphosis (mineralized and micaised) will be classed as metamorphic limestones; while the chemically changed limestones and exotic rocks will be grouped together.

The subdivision of the Methylotic rocks is of such recent date that, from the available records, it is hard to accurately subdivide them unless all the localities were personally revisited. The subdivisions given hereafter are therefore in part only suggestive; but, as far as possible, they will be correct.

In the list will have to be mentioned rocks that are not at all likely ever to be of commercial value as marbles. This, however, appears necessary, as some of them have already been given a greater value than they deserve; and, on this account, it is desirable to mention them.

All of these stones, that are also suitable for cut-stone purposes, are a second time mentioned in the lists of the limestone quarries.

METAMORPHIC LIMESTONES.

The rocks that come under this class—with the exception of the peculiar Sienna-coloured stone in Glendowan, the black stones from near Rathmullen, Co. Donegal, and those of Carricksheedy, Co. Londonderry—are white, or shades of white, some handsome stones being tinted or clouded with grey, pink, or green. All are more or less schistose. Some are thin-bedded, those that are massive generally rising in more or less rude, unshapely blocks. The stones are for the most part coarsely crystalline, and consequently not able to compete with the Italian stones; while those of a creamy character, as far as has yet been discovered, are also disqualified, owing to their being either too thin-bedded or jointy, which prevents them being raised in blocks of sufficient size.

On this account many hand-specimens show a beautiful stone equal to any elsewhere; while, in the quarry, these stones are found to be of such small dimensions as only to be suitable for the manufacture of articles of *vertu*.

This to me seems a most important fact, to which too much attention cannot be directed in Papers on the Economic Geology of the country.

What might be highly productive industries have been already destroyed by false statements in reference to them.

WHITE and RED MARBLES.

[Sometimes tinted, or clouded, with grey, pink, or green; in general coarsely crystalline; rarely fine-grained and compact.]

DONEGAL.

In the promontory of Fanad, north of Kindrum Lough, and immediately west of Lord Leitrim's lodge, is a white stone, partly coarsely crystalline and in part compact. It has not been opened into; but a specimen from the surface gave unsatisfactory results.

Immediately east of the south arm of Sheephaven, in the townland of Drumlackagh, is a considerable thickness of limestone of white to grey tints, some of it being massive, the rest flaggy. Its qualifications for marble have not been tested.

To the eastward of Dunfanaghy, at Marble Hill (Glaisheen), the stone is white or rose-tinted. It is capable of receiving a good polish—crystalline and slightly schistose.

At Ballymore, four miles from Dunfanaghy, there is a creamy-white stone, in places clouded with brown or having brown portions. It polishes well, and has been worked as a marble of a pleasing character.

At Kinclevin, nearly a mile from Dunfanaghy, there is a greyish-white stone not very promising.

Lewis mentions a superior "white marble" in the Rosses, "capable of being raised in large blocks." This ought to be somewhere to the north of Gweedore; but the locality has not been satisfactorily localized.

Six miles E. S. E. of Gweedore Hotel, at Dunlewy, there is a large limestone quarry. The stone is white to creamy-white, tinted with green and pink. It has been used both as building-stone and as marble. The "whites" are coarse, but durable; the others are beautiful stones, but so thin-bedded and jointed that it is impossible to raise them, except in pieces of small dimensions, which renders it of little commercial value. As the quarry has been worked only along the surface of the bed, rarely twenty feet deep, it is possible that better stones might be got at some depth, especially at the western end.

At the base of the range of hills north of Fintown are white limestones favourably reported on. No trials, however, have been made on them.

A little south-east of Glenveigh Castle, a surface trial was made on a white, highly crystalline limestone. Enough of it is not seen to form an opinion; but the rock appears worthy of making a more extensive opening on it.

In the parish of Gartan, on the west shore of Lough Akibbon, and two miles north of Church Hill, is a white, greyish, and pink-tinted stone. It polishes well, and has been approved of by the marble-workers; but further and more extended trials are necessary to prove whether it can be raised in blocks of profitable size.

In the townland of Magheranan, to the east of Letterkenny, is a nice-looking white stone, spotted with green, that has not been opened up, and its qualities are unknown.

In the hills north-east of Kilmacrennan, near the village of Ardanawark, are white and pinkish rocks that can be raised, it is said, in large-sized blocks. No trial has been made on them; but a specimen polished easily and well. They appear to be in the same beds as those at Lough Akibbon.

Three miles south-east of Letterkenny, in Magheraboy, is a nice-looking, white, untried stone.

About a mile east of Convoy, at Kiltale, there is a white stone of good appearance, but thin-bedded.

In various other places in the gneiss district (Cambrian) of Donegal are small detached masses, or beds, of white, or clouded-white crystalline limestones; but as none of them seem to be of a magnitude or quality to form a "quarry," it appears unnecessary to enumerate them.

Galway.

To the south of Letterfrack, in the hill of Creggs, are white limestones. One portion is a stone of "excellent quality, equal to the Italian, but it rises in small blocks" (*Sibthorpe*). After some time spent in sinking on this vein, *Dr. Ritchie* of Belfast failed in getting good-sized marketable blocks.

On the western shore of Derryclare Lough there is a quarry, formerly worked by the *Martins* of Ballynahinch, who seem to

have raised some fair-sized blocks; colour white, tinted with grey. In the lake in White Island there is a very peculiar stone, white, spotted with green Serpentine crystals. This rock is associated with green ophialyte; no opening has as yet been made in it.

South of Adrehid Lake, and in a second place, to the westward of Glengowla Mine, both a little west of Oughterard, there are white crystalline rocks, that have not been tried as yet.

There is also an untried fair-looking white limestone north-west of Ross Lake, between Oughterard and Galway.

Louth.

In the Carlingford promontory white crystalline limestones have been found in three places, but of such limited extent, that it seems improbable that they should ever be of commercial value.

SIENNA-COLOURED.

Donegal.

In Glendowan, westward of Lough Veagh, *M'Henry* records a ribanded Sienna-coloured stone, that polishes well, but it is too thin-bedded to be of much value. Its layer there is a structure like *Eozoon canadense.*

Galway.

At Lough Auna there is a maculated Sienna-coloured stone of limited extent (see page 402).

BLACK MARBLE.

[Black stones in the metamorphic rocks fit for marbles are only recorded in the Cos. Donegal and Londonderry.]

Donegal.

At Kintale, a mile and a-half north of Rathmullen, *Kane* records a stone capable of being used as a marble. It appears to be only very locally known.

Londonderry.

At Carricksheedy there is a black stone capable of taking a good polish; it appears, however, to be only locally known.

METHYLOTIC ROCKS, or SERPENTINES.

The name Serpentine is more applicable to the methylotic limestones than to the methylotic volcanic rocks. We will, however, here use it in the broad popular sense, and include under it all the methylotic limestones and volcanic rocks, also the rocks allied thereto. Of late years Lithologists have greatly subdivided these rocks, the principal subdivisions of the former being called ophiolytes, ophicalcytes, and ophidolomytes; and of the latter, ophyte and eklogyte, with the allied rocks steatyte (*soap-stone*) and pyrophyllyte (*camstone*).

Dana divides the massive Serpentine or ophyte into *precious Serpentine* of a rich old green colour, of pale or dark shades, and translucent, even when in thick pieces; and *common Serpentine* of dark shades of colour, and subtranslucent. The latter is hard and difficult to work on account of impurities. Many statues however, in Egypt and India are made of rocks of this class. Eklogyte is still commonly called Serpentine. Formerly steatite and pyrophyllyte were also thus classed; now many separate them. Steatyte and pyrophyllyte are still confounded together by most people, their appearance being very similar; yet they are chemically very distinct, the former being a silicate of magnesia, and the latter a silicate of alumina. Steatyte seems to be always an adjunct of volcanic rocks, while the other occurs in general as a bedded rock: steatyte, however, may occur as "fault rock," if the latter had been made up of volcanic rock *debris* or volcanic tuff.

METHYLOTIC LIMESTONES AND DOLOMYTES.

OPHIOLYTES, OPHICALCYTES, and OPHIDOLOMYTES.

The rocks of this division now of commercial value are recorded only in the west of the Co. Galway, and are known as *Connemara greens*. They have indeed been found also in the counties Donegal and Waterford, but from neither of these counties do any stones come into the market, while the beds or veins seem to be so limited in extent that there does not appear much prospect of their ever doing so.

The "Connemara greens" are most varied in colour. Some are dark-green, uniform, or clouded; others are leek green or light green; while the majority are mottled or spotted, or streaked and variegated. These last are very happily described by Sir C. L. Giesecke, who wrote near the beginning of the century. "It is impossible to describe the immense varieties of delineations and shades and colours of the beautiful stone which attracts the eyes of the beholder; the serpent-like (*i. e.* wavy formation) delineation of some of them must excite particular admiration. Others are coloured in spiral forms; others are dotted and spotted with different shades of grey and yellow."[1]

GREEN, or VARIEGATED, or STREAKED with GREY, WHITE, RED, YELLOW, PURPLISH.

GALWAY.

The ophialites occur in one group of strata which were once continuous, but now, on account of the breaking-up of the rock by faults, the exposures are more or less disconnected and isolated. The most northern exposure occurs as an isolated mass at Loughnagur range, two miles south of Barnaderg, or Ballynakille Harbour. The rocks are uniform, clouded, and variegated green. The stone has not been worked in this locality. The nearest harbour to it is Barnaderg, with which it might easily be connected by a road.

At the west end of Streamstown Bay, or about two miles north of Clifden, are different exposures of ophicalcyte. On a vein a little east of the end of the bay is the quarry formerly worked by the D'Arcys of Clifden, and of late years by Mr. Colles of Kilkenny. The stone in general is variegated with spots or streaks; green, grey, and white predominating. The scabbled blocks are carted to Clifden for shipment.

In the eastern continuation of the Streamstown Bay valley, occupying a narrow tract over three miles long, which extends from Loughauna to Loughnahillion, is a nearly continuous band of these rocks. Here there is a great variety, both in beauty and colour, as

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[1] *Trans. Royal Dublin Society*, vol lxii., March 2, 1826, Appendix.

exhibited in the ornaments manufactured by the M'Donnells of Clifden—self-taught artists—who manufacture brooches and various other articles of *vertu* by hand, out of ophialytes from these and all the other localities, to dispose of them to visitors. One unique and beautiful variety on sale by Alick M'Donnell was a maculate Sienna-colour ophialyte from a vein at Loughauna. To work the stone in this valley, that to the westward, near Loughauna, could best be approached by a road constructed from Streamstown Bay, from where it could be carted to Clifden for shipment; while that at Loughnahillion would be brought more easily by a road northward to Barnaderg Bay.

To the south and south-eastward of the valley last mentioned, and nearly parallel to it, is that of the Owenglin; where, in occasional spots for a distance of over three miles, the ophialytes appear. They are, as elsewhere, most varied in colour and beauty, while in some of the streaked varieties the structure that has been called *Eozoon canadense* occurs. In this valley, at Barnaoran, are the famous "Ballynahinch Marble Quarries," from which, in old time, most of the Connemara marble was obtained; and it was of the stone seen here that Geisecke wrote. Of late years these quarries have got into disrepute, on account of the severe road from them, a steep ridge intervening between Owenglin and Ballynahinch, over which the blocks had to be carted. This stone was used in the new Museums at Oxford and Trinity College, Dublin. A small vein of a peculiar variety (*Onkosin*) occurs to the east of Barnaoran; it is of a pale olive greenish grey colour, full of dendritic markings, and having an appearance somewhat like moss agate. This, under the name of "moss serpentine," was extensively worked by Alick M'Donnell, who discovered it. A very fine specimen is in the Museum, Queen's College, Galway.

The blocks of stone from this valley have to be drawn across the ridge to the Ballynahinch valley, and from thence to Cloonisle pier for shipment; they might, however, be manufactured by water power at the quarries.

Extending southward, at nearly a right angle from the east end of Owenglin, is Glenisky. Here the serpentine occurs in veins that continue southward from those in Owenglin, along the western slopes of Bengower, past the summit of Benlettery, terminating on the south slope of the latter. The stones are very similar

to those in Owenglin, but with them are also found smaragdite schist. The place is difficult of access; because Glenisky, leading down to Ballynahinch, is steep and rugged. Blocks might, however, be run down an incline, or the marble might be worked in the glen by water-power. The south end of the glen is about five or six miles from Cloonisle pier.

In the south-east slope of Benlettery there is the small east and west valley called Derrynagloan, where there is a small vein. This is of easy access from the Ballynahinch road.

Extending northward from the east end of Ballynahinch lake is Glencoaghan. Here are found, in different places, detached exposures of serpentine, the largest occurring at, and southward of, Bennaderreen, on the western slope of Derryclare hill. The other exposures are between this and the lake. The stones are very similar to those in Glenisky. No quarry as yet has been opened; nor is there a cart road into the glen, but one could easily be constructed, which would pass by all the exposures. Canal Bridge, at the mouth of the valley, is about seven or eight miles from Cloonisle.

Veins of serpentine occur in places along the north-east portion of the south-east shore of Derryclare lake, and also in the islands. Here, especially in White Island, the rocks appear to be more varied in colour than elsewhere, one being very peculiar, having in a whitish ground long, crystal-like pieces of dark green. Most of the veins are at the water level, and, if they were worked, there would be a certain amount of expense in pumping. The blocks, however, might be carried by water down the lake to Canal Bridge, and even down Ballynahinch Lake to the river near Toombeola, where they would be only a short distance from Cloonisle.

Farther eastward, to the northward of the Recess Hotel, on the south-west and north-west slopes of Lissoughter, are various detached exposures of serpentine. On the south-west slope, close to the village, is a quarry formerly worked to a slight extent by the Martins of Ballynahinch, but much more extensively during the last fifteen years by the Messrs. Sibthorpe of Dublin. This stone is, in general, uniform, or clouded green, some being dark, but at the same time translucent. Very good-sized stones have been raised, but in rough, unshapely blocks. The stone, however, is of

such good quality, that it has been found more profitable to carry them unsquared to Cloonisle for shipment than to square them in the quarry.

At the time the Messrs. Sibthorpe began working, about the year 1870, there was a considerable demand for "Connemara greens"; but unfortunately for the reputation of the stone, as also for many other marbles, architects would insist on using them in outside decorations, and, consequently, not through any real inferiority in the stones, they soon weathered and became unsightly. Thus was generated a most undeserved prejudice against the green marbles, which, when used in their proper sphere as inside work, cannot be surpassed in beauty or elegance.

The largest column yet obtained (9 ft. 9 in.) was wrought out of a block raised in Lissoughter. It is now at St. Anne's, Co. Dublin, the mansion of Lord Ardilaun. In England this marble was used at the Manchester Exchange, Rochdale Town Hall, St. Mary, and other places in Bradford; St. John's College, Cambridge; St. Mary Abbot's, Kensington; St. Pancras Hotel and Station, &c. Recently it is being exported to America, there being a greater demand for the uniform and clouded dark-greens than for any of the others. From either the Lissoughter or Barnaoran quarries was procured the serpentine, by the Martins of Ballynahinch, that was wrought into the chimney-piece presented to George IV., and now in the Carlton Club, London.

METHYLOTIC EXOTIC ROCKS.

(Ophyte, Eklogyte, Steatyte, and Pyrophyllyte.)

DARK-GREENS, and VARIEGATED.

The ophytes, as a general rule, may be classed as "dark-greens," although some are of light colours, or spotted, mottled, and streaked. None of them appear to answer fully Dana's definition of "Precious Serpentine," as they seem in general to occupy a position between that grade and his "Common Serpentine." None of them are in the market, although they are equal to, and perhaps even surpass, some of the foreign stones.

They are not, comparatively, of rare occurrence, being recorded in seven counties, while probably they will be found in others, as until recently it has been customary to group them with the associated pyroxenic or other volcanic rocks, of which they are methylotic adjuncts. Thus, in the counties Wexford and Wicklow, it is only recently that these distinct rocks have been separated on the maps.

As far as the records can be depended on, these rocks are, in almost all cases, found associated with the old metamorphic rocks (*Ordovician* and *Cambrian*). One exception, however, has been mentioned, as ophyte is found as an adjunct of the *Carboniferous* rocks of the Co. Limerick. Here the tract is of such small dimensions and the rock so inferior in quality, that it might be ignored were it not for the exceptional circumstances under which it has been found. It is quite possible, however, now that attention has been called to the circumstance, that it may be found elsewhere associated with even younger rocks.

Eklogyte is in aspect very like ophyte, and by most geologists they are classed together. It has therefore been only recorded in two counties, although probably it also occurs elsewhere. It is allied more or less closely to saussuryte, or Swiss jade. Some of the ancient implements known under the general name of "celt" were manufactured out of rocks of this class.

The steatytes or soapstones are in colour very pale-grey, or bluish, or greenish, or greyish-white, while others are reddish or orange. Some of them are very suitable for the manufacture of articles of *vertu*, but as far as we are aware they have not been so utilized.

Pyrophyllyte or camstone may be counted as a new class of rock; for although given its proper place in mineralogical books, in geological writings it has almost invariably been called steatyte, or a "coarse variety of steatyte"; consequently the records of its occurrence are few. For years it has been recognized in the Co. Donegal, and has been used in some of the ecclesiastical structures. A rock that appears to be pyrophyllyte is also recorded in the Co. Cork; while patches and veins or beds occur in the blackish slates of Ordovician age in the Co. Wexford. In other places, if it exists, it has been classed with steatyte. It probably occurs in the Co. Galway, as hereafter mentioned.

OPHYTES.

[Dark-green to blackish, some striated and spotted. Occur in the Cos. Galway, Mayo, Sligo, Tyrone, Waterford, Wexford, and Wicklow.]

Galway.

To the north of the townland of Leamnaheltia, near the south shore of Lough Fee, in the mountainous tract north of Kylemore Lough, is an isolated mass of ophyte of dark, and in places lighter clouded greens. Some pieces of this rock were worked by Alick M'Donnell of Clifden, who stated "the rock was very kind."

At Dawros, to the east of Ballynakille Harbour, and a little north of Letterfrack, there is an extensive tract of dark-green, nearly black, ophyte.

To the south and south-west of Garroman, or Glendollagh Lake, are small tracts of dark-green ophyte.

Near the shore of Galway Bay, about half a mile south-west of the ruins of Bunowen Castle, is a small tract of dark-green, nearly black, ophyte.

In the mountainous tract of Errisbeg, to the westward of Roundstone, are three rather long tracts of ophyte. Two are near Lough Bollard, while the third is a little more than half a mile to the east of it. The stone in general is dark-green, but some of it is mottled, dark and light.

Mayo.

Two miles north of Castlebar there is a long narrow exposure of dark to light-green ophyte.

Along the northern slope of the Croagh Patrick range, from near Louisburg to some miles east of Westport, is a long wide tract of ophyte associated with steatyte. To the westward it thins out, while its greatest thickness appears to be at the railway cutting a mile and a-half south-east of Westport. Some surface-specimens were experimentalized on and were found difficult to cut; but it might improve if opened in depth; it appears worthy of trial, as it varies much in colour, from greenish-black to dark-green, light-green, reddish, and purplish; some of it being handsomely streaked with the colour last mentioned.

In the hills between Leenaun and Wesport, two or three miles north-west of Sheffey, at and south-west of Lugaloughaun, are three or four exposures of a peculiar rock that appears to be allied to ophyte; they are of different shades of light green. These rocks work easily, but it is questionable if they could be procured in large blocks. The place at present is very inaccessible.

In Glencullin, north-east of Mweelrea, is a dyke of mottled-green rock allied to ophyte, or eklogyte (?).

SLIGO.

At Slishwood and the valley running nearly south from Bunowen Bay, Lough Gill, is a band nearly two miles long and about five hundred feet wide, of a dark-coloured, compact, somewhat hard ophitic rock. It contains magnetite, especially to the westward, where Hardman states it "possesses all the characters of natural magnets." It also contains some nickel. The rock is of a splintery nature. Although called a serpentine, it possibly more correctly should be classed as an eklogyte.

At Drumahaire, three miles north-east of the Slishwood serpentine, there is a band about three hundred feet thick of very similar rock, except that it is not "perceptibly magnetic."

Close to Shanavan's Bridge, near Manorhamilton, is a third band of similar rock, supposed to be about a mile long.

In the *Geology of Ireland*, p. 191, it is suggested that these rocks were possibly metamorphic Cambrians or even Laurentians. It now, however, appears to be much more probable that they are in part Cambrian, and in part Ordovician.[1]

TYRONE.

Westward of Cookstown, to the north and north-west of Pomeroy, are the hills in which Slieve Gallion is the principal

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[1] If the markings found near Lough Finn, Co. Donegal, and exhibited by Dr. Hull at British Association Meeting, 1886, are graptolites of Arenig types, as appears to be very probable, the supposed Laurentians of Donegal are unquestionably metamorphosed Ordovicians, Arenigs, and Cambrians. Consequently, it is probable that the rocks of Sligo, and also the similar rocks of Cos. Tyrone, Leitrim, and Mayo, are also Cambrian, Arenig, and Ordovician.

summit. These, for the most part, are composed of highly altered rocks that have been suggested to be of Laurentian age; but, as previously mentioned, are more probably metamorphosed Arenig. In them, towards their south margin, are tracts of ophyte, generally dark olive-green, approaching to black, but some are of lighter colour or variegated or streaked.

About three miles north-west of Pomeroy, west and south-west of the lake that lies half a mile west of the summit of Cregganconroe, are four distinct patches of ophyte; while a little to the west, on the hill called Scalp, is a fifth. At Athenree, about a mile and a-half S.S.W. of Scalp, and a mile south-east of Carrickmore or Termon rock, there is also a tract, and another about half a mile W.N.W., of Carrickmore. In the last, the rock, in places, has a decided variegated or streaked colour. Some of these stones have a good appearance, and seem to be qualified to produce a marble. As yet, none of them have been utilized or even tested.

Waterford.

In this county the serpentines recorded are only of very small extent. As, however, the rocks of the eastern portion of the county are similar to those of the adjoining counties of Wexford and Wicklow, and as among the latter ophyte only recently has been recorded, it formerly having been included among the pyroxenic rocks, it seems not improbable that here, as in Wicklow and Wexford, there may be small tracts of ophyte still unrecorded. This, however, has still to be examined into.

Wexford and Wicklow.

The presence of ophyte was not recorded in these counties until within the last five years, although "serpentine" is mapped on the old geological six-inch maps. This, probably, is due to the fact that, until recently, many geologists classed them with the pyroxenic rocks, of which they are metholotic varieties. They are now known to occur in the following localities:—

On the north and south slopes of the western spur, extending from Croaghan Kinshella, in the townlands of Cummer, Cummer-

duff, and Hillbrook, some of them being on the borders of the counties of Wexford and Wicklow, are detached exposures of ophyte. They are of various shades of green, generally dark-coloured.

South-west of the spur of high ground last mentioned, and a little west of Carnew, in the Co. Wicklow, there is a tract of dark-green ophyte, in places spotted with red, like a bloodstone. It is capable of taking a good polish.

Much further northward, about half way between Anamoe and Togher or Roundwood, is a large boss of dark-green ophyte.

EKLOGYTE.

[Speckled and mottled, green and brown, recorded from Galway, Mayo, and Sligo.]

GALWAY.

To the W. N. W. of Kylemore Castle, in the townland of Currywongaun, there is a vein of greenish-brown speckled eklogyte. A small opening was made by Mitchell Henry, M.P., who had some of the rock cut and polished at his saw-mill.

A little south of Garroman or Glendollagh Lake, in the mass of ophyte previously mentioned, is a pipe vein of spotted bright-green eklogyte.

MAYO.

A little south-west of Ballyhean, on the north slope of Tonaderrew, there is a mottled light-green eklogyte. The rock in this locality is very like the previously-mentioned rocks near Lugaloughaun and in Glencullin (see *Ophytes*, page 406), and it is possible that the rocks in these places should be classified with the eklogytes, and not with the ophytes.

SLIGO.

The rocks previously described among the ophytes, at Slishwood, Drumahair, and near Manorhamilton, seem to partake very much of the nature of eklogyte, and possibly ought to be so classed.

STEATYTE, or SOAPSTONE.

[Some are pale-grey, of bluish and greenish tints; others reddish or orange. They have been stated to be found in the Cos. Donegal (?), Galway, Mayo, Sligo, and Waterford. As the question of the classification of steatyte and pyrophyllyte is still obscure, rocks said to be steatyte will be mentioned under this heading, coupled with the objection to their classification.]

Donegal.

In different places associated with the basic volcanic rocks are seams of steatyte, but of very small dimensions. In other places, the rocks that are generally called steatyte are more probably pyrophyllytes. No large mass of true steatyte appears to be recorded in the Co. Donegal.

Near Crohy Head, westward of Dunloe, Mr. Blake states there is a steatyte so pure as to be valuable for the manufacture of lubricators. It occurs as a bedded rock unassociated with intrusive rocks, and is probably a pyrophyllyte; but this has still to be verified.

Eastward of Dunfanaghy, at Ards, steatyte is also said to have been found. The rock, however, appears to be pyrophyllyte.

Galway.

Steatyte occurs in subordinate veins and patches, associated with many of the intrudes, especially the ophyte; but they are of small dimensions. It has also been recorded as found near Kilmeelickin chapel, in the Maum valley. The specimen, however, would suggest that the rock was a pyrophyllyte.

Mayo.

On the south shore of the island of Bofin and the north shore of the island of Shark, in this county (but off the coast of Galway), are considerable tracts of fine light to darkening-grey steatyte; the better portions being of a silver-grey. On Bofin it has been worked to some extent, and exported for the manufacture of lubricators, but apparently not for articles of *vertu*.

In the mountainous tract between the Killary and Clew Bay, to the westward of Doolough, there is a considerable mass of an impure yellowish steatyte, an adjunct to a felstern intrude.

Associated with the long ophyte mass of the Croagh Patrick range, there are steatytes of greater or less extent in different places.

WICKLOW.

To the eastward of Croaghan Kinshella, in the townland of Killahurla, there are in places dykes of a reddish or orange friable steatyte. None of these have been opened in depth.

PYROPHYLLYTE, or CAMSTONE.

[Pale greyish-green to dark-green. When cut and polished some are of a rich olive-green. They are only recorded in the Cos. Cork (?), Donegal, Galway (?), and Wexford.]

CORK.

In the carboniferous slate, to the south-west of Castletown Berehaven, are beds or dykes of a pale-yellowish stone that are probably pyrophyllyte or an allied rock; they, however, require further examination.

DONEGAL.

In this county camstone appears to have been recognized for years, although in the records it has been called "a coarse or impure kind of steatyte"; and has even been mined and sent into the market as steatyte. Years ago it was used for architectural purposes, as in the ancient churches of Balleekan and Killydonnell south and north, respectively, of the western arm of Lough Swilly, where, when the Old Sandstone mullions of the windows decayed away, they were replaced by new ones cut out of camstone. In Balleekan there are also tombstones of a somewhat similar class of rock. Where this stone was procured is now unknown. Wilkinson, writing in 1845, states that in the mountain range, near Kilmacrennan and Barnagh are camstones that "can be cut or turned with facility into any form," and "are very durable," but the localities are not given, and no quarries in this stone appear to have been worked for years, or can now be pointed out in those neighbourhoods. It is, however, known to occur in the following places:—

About two miles N.N.W. of Castlefin, at Gibbstown, is a quarry

from which camstone appears to have been procured rather extensively in former years; at present it is only raised to be used for hearths or the backing of fire-places.

In places between Raphoe and Letterkenny camstones have been found, but they seem to be only used for local purposes.

In the townland of Cabrabrook, E. S. E. of Church Hill, is a camstone that appears to have been quarried formerly, but for years the quarry has been filled up.

In Carrowtrasna, west of Lough Akibbon, and over two miles northward of Church Hill, is a bed that has been mined by Mr. Duckworth for some years, and sent to Liverpool, to be used in the manufacture of lubricators; but on his death a few years ago the industry was abandoned.

Beds of camstone associated with limestone can be seen in different places in the hill country westward of Kilmacrennan, but it does not appear to have been worked recently except to get clay for hearths. At Cloonkilly there was a large working; it is probably the locality referred to by Wilkinson

There is a bed or beds to the north and north-east of Ramelton and in the neighbourhood of Carn it has been worked along the surface to obtain fireclay.

Westward of Rathmullen, in the townland of Meenreagh, there is a bed of camstone.

LIMESTONE QUARRIES.

[The quarries will be arranged in the counties placed alphabetically under their geological group. Generally only the quarries that give stones fit for cut-stone purposes will be mentioned, except in counties where limestone for burning is scarce, under which circumstance all the localities are given. In some localities, where quarries are scarce or altogether absent, limestone boulders are found in the drift, and are collected along the sea-coast, river, and streams; while in other places sea-shells are carried inland and burned. Tradition says that lime made from sea-shells was used as a medicine.]

Antrim.

In this county there is no Carboniferous limestone except what occurs as subordinate beds in the Ballycastle coal-field; and in these no quarry of any note seems to have been worked.

The Cretaceous, or White Limestone, occurs round the margin of

the great field of Cainozoic dolorytes, principally near the coast-line. Many quarries have been opened in it, generally to procure stones for lime. As the White Limestone is for the most part full of irregular cracks and joints, it cannot be finely tooled or procured in large blocks; it can, however, be scrabbled into fair-sized stones suitable for rough building. A house built of the White Limestone, with quoins and dressing of the black doloryte, has a clean but quaint appearance.

In pre-historic times the chalk flints were extensively manufactured into weapons and other articles in the county, or were exported into the neighbouring counties. Subsequently they were manufactured into gun-flints. The latter trade has now died out, although still found profitable in parts of England.

The white limestone in general gives a good and cheap lime. It is largely quarried, and exported to the opposite coast of Scotland for the purpose of burning.

At Larne and Glenarm the white limestone is extensively manufactured into whiting.

ARMAGH.

A limited tract of Carboniferous limestone occurs across the north portion of the county. In general it is of an earthy character, inclined to be shaly, and blackish-grey in colour, except at Armagh.

Armagh.—Light pinkish grey, yellowish, and shades of red. This stone, when polished, gives out a warm yellowish colour; but when dressed with the tool it is whitish. It is used as marble, and both for rubble and cut-stone purposes. Blocks of large size, suitable for columns, have been obtained, while the thinner beds of red shades have been made into chimney-pieces and other ornamental work. Formerly these quarries were very extensively worked (see *Armagh Marbles*).

Navan. A mile from Armagh.—Dark, dull, grey, earthy; rather difficult to work.

Excellent lime is abundant at Armagh, and a good lime, made from the white limestone of Co. Down, in the neighbourhood of Lurgan and Moira, is also much used.

At Benburb, adjoining the Co. Tyrone, there is a compact blue stone that makes hydraulic lime. It was used in the construction of the Ulster Canal.

Carlow.

In this county the greater portion of the Carboniferous limestone is a dark iron-grey dolomyte, of a frail nature. Near the town there are limestones of the Calp type, some of them being in good blocks. The quarries in the latter locality have been worked more for the marble than for building-stones. These quarries have been already mentioned (see *Black Marbles*).

Brownhill. A mile north-east of Carlow.—The stone in general is dolomyte, full of drusy cavities (geodes); but one bed, between 4 and 5 feet thick, consists of grey, compact, and fine-grained stone, capable of being dressed.

In general, the limestone of the county burns into excellent lime.

Cavan.

Very little good limestone for building purposes can be obtained, except at the extreme south of the county, near Lough Sheelin. Formerly some quarries were open here, but now all stone is procured from the Ross Castle quarry, close by, in the Co. Meath. Near Cavan some small quarries have been opened, but the stone is not generally valued for tool-work.

Belturbet.—Light to dark-grey, fine, crystalline, but splintery; thick and thin-bedded. Tools fairly. From this vicinity were procured the stones to build Crom Castle, on Lough Erne, Co. Fermanagh.

Mount Nugent.—Quarries were formerly worked in this vicinity on a stone of good quality. They are now closed up, as all stones required can be more easily obtained from Ross Castle, Co. Meath.

A fair, strong lime is made from the Cavan limestone. In the southern portions of the county most of the lime is procured from the neighbouring counties.

Clare.

Throughout most of the barony of Burren and in the country near Ennis, there are large tracts of bare rock. The stone is of the Burren type, and is, in general, of excellent quality; but some beds are much cut up by joints; others, however, are not, and from these stones of great dimension can be procured. As the

limestone can be worked on the surface in so many places, very few quarries have been opened: the stones procured at some depth are, however, much more easily worked than those obtained at the surface.

Rosslevin. One mile from Ennis, where the stone is extensively used.—Dark-grey, semi-oolitic, crystalline, and close-grained. Works freely: but as the stones are of small dimensions they are procured at Bushy Park when required for larger size.

Bushy Park. Over two miles from Ennis.—Somewhat like the Rosslevin stone, but can be raised in much larger blocks.

Kilfenora. Over six miles from Ennistymon, where the stone has been largely used.—Grey to dark-grey. Rather difficult to work. The great durability of the stone of this neighbourhood, and its capability of being used in fine work, is seen in the ancient crosses and the cut-stone work of the ecclesiastical ruins. Ancient work in Burren stone can also be seen in the ruins of Corcomroe Abbey, near Ballyvaughan. In connexion with the latter, the tradition in the country is, that the stones were procured in a cleft south-east of the summit of Moneen mountain, called "Scalp-na-Shesbia," but this seems to be a natural ravine, and due to weathering.

In the south and south-east of the county quarries have been opened in various places for local purposes. South of Newmarket-on-Fergus there is a quarry in a red or reddish-grey stone, that was used in the building of Adare Manor, Co. Limerick; it has also been worked for marble.

The stones of this county make excellent and cheap lime. Along the south-west coast sea-shells used formerly to be burnt for lime.

Cork.

In comparison with the extent of the county, there is not much Carboniferous limestone in it. It principally occurs in the valley of the Lee, near Cork, and thence eastwards to Youghal; also in the valley of the Blackwater. Many of these stones are remarkable for their beauty. Macaulay has made the beautiful stone of which the Courthouse of Cork is built historical.

Aherla. About nine miles north of Bandon.—Light-grey, platy, very easily worked; can be sawn with advantage, and large

flat stones can be procured. On account of the great ease with which this stone can be raised and worked, it is cheap, and has a considerable sale, even in Cork, nineteen miles distant.

Ballintemple and *Carrigmore.*—Three miles from Cork. Light-grey, close, even-grained, and compact; works well and freely. This stone has been used extensively in the public buildings in Cork; among others in the Courthouse, as mentioned by Macaulay. The capitals of the columns of the portico are well executed.

Haulbowline.—Light-grey, not very easy to work; can be raised in large blocks. Used in building the new docks.

Little Island.—Light-grey, close-grained, and compact; works freely. Was extensively used for the fortress at Spike Island.

Carrickacrump and *Ballyfin.*—Near Cloyne, and about twenty miles by water from Cork. The stone is carted to Aghada for shipment. Very similar in character, except as regards colour, to the Ballintemple stone, with which it does not contrast well. The Bank of Ireland in Cork was built of stone from this place. It can be raised in very large blocks, and can be more easily sawn and worked than any other limestone in the neighourhood of Cork Harbour. Ballyfin is about a mile from Carrickacrump, and the stone there has not been as largely worked.

Fermoy.—Light bluish-grey, compact, but of variable texture.

Ramaher (Kanturk).—Grey, compact, very fossiliferous; not easy to tool, on account of the fossils.

Midleton.—Greyish-blue, inclined to reddish, compact, semi-crystalline, uneven in texture. Has been worked as a marble.

Shanbally. Near Carrigaline.—Light-grey, of a flaggy nature; an excellent stone for rubble work; not so good for dressed work.

Fairlane. Near Mallow.—Light-grey, compact to splintery; close-grained; works fairly.

Drishane. Two miles north-east of Millstreet.—Grey, compact, but in places having drusy cavities; works fairly well; quarried very largely for lime.

Carraundulkeen. Three miles south of Kanturk.—Dark-grey, crystalline; semi-compact; works well; very largely quarried for lime.

In the limestone areas the lime, as a rule, is excellent and cheap. At Kinsale there is a bad lime brought into the town. In places along the coast sea-shells used formerly to be burnt.

The dolomytes of this county have been utilized for the manufacture of fluid magnesia.

DONEGAL.

The areas of Carboniferous rock are of very limited extent, the largest being that in which Donegal and Ballyshannon are situated. At Pettigoe there is a little strip outside the mearing of Fermanagh. There are, however, in various places among the metamorphic rocks (Ordovician and Cambrian), beds and patches of the older limestone. Some of these are well suited for cut-stone work. The cut stone in the little church of Glenalla, near Rathmullen, is from this class, and has a remarkably good appearance, and seems to be durable. The white and shaded whites, of which there are many varieties, are capable of being polished, and might be worked as marble; but almost invariably they are more or less coarsely crystalline; or when fine-grained and compact, they are thin-bedded and full of joints, preventing their being raised, except in small pieces. These causes deteriorate their value, and prevent their being able to compete with the Italian stone.

In the Metamorphic Rocks (Cambrian (?), Arenig, and Ordovician) limestones occur at the following places:—

Ballymore. Four miles from Dunfanaghy.—Creamy white, in places clouded with brown, or having brown portions; highly crystalline; polishes well. Has been used as a marble. Difficult to work, but an excellent material for all cut-stone purposes.

Marble Hill or *Glaisheen.* Two and a-half miles from Dunfanaghy.—Pink and white, of a delicate colour, but with imbedded clouds of grey; crystalline and slightly schistose.

Rock Hill.—One and a-half miles from Dunfanaghy. Whitish-grey, slightly crystalline, in parts pyritous and micaceous, making the stone liable to discolour.

Rinclevin.—Nearly a mile from Dunfanaghy. White, with greyish tint; highly crystalline; fracture smooth.

Dunlewey. Six miles E. S. E. of Gweedore.—White and pink-tinted creamy white; blue, and green-tinted. At the western end of the seam there was a hard, white crystalline rock, very durable, as seen in the church close by, where it has not even lost colour. This stone was not followed in depth. The creamy and tinted varieties in the eastern portion of the quarry are in very thin beds,

and are so broken up by joints that they cannot be raised except in very small pieces.

Lettevy. Over two miles from Glenties.—Light whitish-grey, silicious, and micaceous. In this vicinity are other quarries from which similar stones can be procured.

Fintown. To the north of Lough Finn.—White to greyish crystalline.

Glenveagh. A little south-east of the Castle.—White: highly crystalline. Only the surface of this bed has been opened. Here it is friable and much cut up by joints. Stone untried in depth.

Lough Akibbon (Garton). Over two miles north of Church Hill. —White and pinkish, solid, fine, crystalline; polishes well; seems capable of being raised in large blocks. Appears to be an excellent material for all cut-stone purposes; but as yet the quarry has only been very partially tried.

Drumlakagh. Nearly three miles eastward of Creeslough.—White and grey-tinted; crystalline; thick and thin-bedded. Could be raised in fair-sized blocks. Not at present worked, except for lime.

Ardanawark. Two miles north-east of Lough Salt, in the hills north-east of Kilmacrennan.—White and pinkish, highly and coarsely crystalline. Can be raised in large blocks. Appears to be well suited for tool-work, but at present only worked for lime. Polishes well and easily.

Magheraboy. Three miles south-east of Letterkenny.—White to pinkish; very crystalline. This stone seems to be totally unworked, although, from its appearance, it ought to give good lime, and be suitable for cut-stone purposes. As it is near Letterkenny, in which neighbourhood there is no stone of any kind suitable for tool-work, this seems worthy of a trial.

Cloghroe. Two and a-half miles from Stranorlar.—Bluish-grey and white; crystalline; partly schistose.

Cullanacon. Two miles west of Convoy.—Greyish-white and pink-shaded; crystalline; thin-bedded, with schistose partings.

Kiltole. Nearly a mile east of Convoy.—White to pinkish; compact; crystalline. A good stone, but thin-bedded.

Maghera-sollus. A mile E. N. E. of Raphoe.—White and greyish-white; compact; crystalline; thin-bedded, with schistose partings.

Crauford. Four miles northward of Milford, on Mulroy Bay. —Light to dark bluish-grey; compact to shattery; crystalline; in part schistose; makes excellent lime.

Kindrumlough. A little west of Kindrum Lodge, in Fanad-within-the-Waters.—White to creamy white; coarsely crystalline to compact; shattery, but seems to be suited for tool-work. As yet untried. Surface-pieces polished well, but were shattery and facial.

Tamney. West of Croaghan House.—A dolomyte of a Sienna character. Untried, but appears too gritty and irregular to be of much value.

Kintale.—A mile and a-half northward of Rathmullen, on Lough Swilly. Bluish-grey, in part earthy and in part micaceous. Works easily; can be raised in large blocks. One black bed has been locally used as a marble.

Hill Head. Four miles from Carndonald.—Dark blue to grey; finely crystalline. This stone has its peculiarities; because when first raised, it is soft and crumbly, but afterwards it hardens into a good stone.

Various other detached masses occur also in different places in the hills, but it is unnecessary to enumerate them.

Good or fair stone in the Carboniferous is recorded as follows:—

Ballyshannon.—Brownish-grey to dark greyish-blue; earthy; compact; semi-crystalline; works freely.

Donegal.—Greyish-black; very earthy, the calcareous matter being very small. Not much used.

The *Carboniferous* limestones near Donegal and Ballyshannon burn into a good lime. The older limestones *Ordovician* and *Cambrian,* are very generally used, the lime being nearly invariably dark-coloured, but strong. Some of the white varieties, however, give a white lime. A peculiarity of some of these limestones is, that when they are used as road-metal, the road becomes plastic in continuous wet weather, becoming again quite hard when it is warm and dry.

DOWN.

This is one of the Irish counties in which there is scarcely any Carboniferous limestone. It occurs only in a small tract at Castle Espie, two miles south-east of Comber, and in the extreme south

end of the county at the entrance to Carlingford Lough. The stone at Castle Espie is worked solely for lime.

At Cultra, on Belfast Lough, a little Carboniferous limestone, associated with Permian dolomyte, occurs below high water-mark.

Cretaceous, or the White Limestone, occurs in the west of the county, in the north-west slope of the valley of the Lagan. It is worked largely for lime in the neighbourhoods of Moira and Lurgan. It is too brittle and jointed to be finely tooled or procured in large blocks, but it can be squared by scabbling into blocks suitable for rough masonry.

Lime in this county is scarce, most of it being imported. It is procured from the Carboniferous limestone at Castle Espie, and from the White Limestones of the Lagan Valley. In places on the coast sea-shells were formerly burned into lime.

The Permian dolomyte of Cultra, on Belfast Lough, was formerly utilized by being exported to Glasgow for the manufacture of sulphate of magnesia.

Dublin.

Nearly all the limestone in this county is more or less of the Calp type, and varies greatly in character. In general it is only suitable for rubble-work; but as it can be raised in large sizes it is valuable for foundations. Some beds make good lime, while adjoining beds may not burn at all.

The best stones occur near Lucan and Leixlip, near the mearing of the Co. Kildare, from whence they were procured for the Custom House Docks. Calp limestone was also used in the building of the old church in Mountjoy-street and the old Christ Church Cathedral, while the latter was repaired by Calp brought from Rathgar and Kimmage. For many of the old buildings the stones were so badly selected, that they are now weathered into rotten shaly or earthy masses.

In the north part of the county there are stones of a coarsely-crystalline character, not well suited for tool-work, but capable of being raised in very large blocks.

Milverton.—This and other quarries occur in the neighbourhood of Skerries. Grey, coarsely crystalline, compact, and even-bedded. Rather hard to tool, and not well suited for fine work; but, on account of its strength and the possibility of procuring it in large

blocks, it is suitable for massive work. From this were obtained the large cap-stones for the pillars of the Boyne Viaduct. They were also extensively used in the construction of the Lighthouse on Rockabill.

Donnybrook and Miltown.—Here formerly were extensive quarries, principally in the river and to the eastward of it, but now they are very little worked. Dark-grey to blackish, earthy; suited for foundations and rubble-work, but not for cut-stone. It was, in a great measure, the use of the Donnybrook Calp in repairing the streets that got for Dublin the *soubriquet* of "dear, dirty Dublin."

Rathgar.—From pale to dark-grey and blackish; from thick-bedded to good flags. This quarry was once extensively worked. The ordinary stones were good for rubble-work, and the flags of a very fair quality. The best beds, being nearly equal to the "Carlow flags," were extensively used.

Kimmage and Crumlin.—The stones in these quarries are more or less similar to those at Donnybrook, Miltown, and Rathgar. These supply to a great extent the rough and foundation stones now required in Dublin.

Ballymacauly and Collierstown.—On the Royal Canal, between Leixlip and Lucan. From these quarries were taken the stones to build the Dublin Custom-house docks. Formerly very extensively quarried.

Lime from the Calp is, in general, dark-coloured and inferior, some beds being, however, very good. A great deal of the limestone used in Dublin for lime is brought from the neighbourhood of Slane, Co. Kildare.

At the present time the limestone which appears to be most approved of by the Dublin builders is the Ballinasloe, Co. Galway, stone, which can be seen in the Hibernian and Munster (Head-office) Banks; next to it the Tullamore, King's County, the latter being much in request for monumental purposes, and was used in the monument at Glasnevin to the late Under-Secretary, Mr. Burke. The Ardbraccan stone, Co. Meath, although it has a good appearance when finished, is soft, and does not keep its colour; and with it is classed the Ross Castle stone, Co. Meath; but the stone from the neighbouring quarry at Crossagh, although coarser, is more favourably thought of. The Milverton stone, near

Skerries, works easily, but is full of verts and defects. The Sheephouse stone, near Drogheda, was used in the restoration of Christ Church Cathedral, although it has the reputation of being of a soft, poorish class.

Fermanagh.

In the centre of the county, forming the valley of the river and the two loughs Erne, there is a considerable tract of Carboniferous limestone; but in some places the stone is of a bad quality, not being even fit for lime-burning. Where good stone does occur, it is not as much sought after as in other counties, the sandstone being of good quality, and very generally used for dressed work. In the erection of Crom Castle, the seat of the Earls of Erne, limestone from Belturbet, Co. Cavan, was used; but the quoins and dressings are of sandstone. Most of the public buildings in Enniskillen, as also in the other towns, are built of limestone.

Kinarla. About a mile and a-half by water from Enniskillen. —Dark-grey; not a sound stone; was used in building the church and part of the Roman Catholic church in Enniskillen; also by the Ordnance Department.

Derrygon. Half a mile from Enniskillen, on the lake shore.—Dark-grey, compact, good quality; used in the gaol and the new bridge built by the Drainage Board.

Mullaghree. Two miles from Enniskillen.—Light-grey, sound, tough, flat-bedded.

Carrickreagh. Five miles by water from Enniskillen.—Dark-grey to black, of excellent quality; polishes well; has been used extensively in Enniskillen; lately in the new cemetery church, and as quoins and dressings in the Roman Catholic church; also used for tombstones.

Kesh. One mile from the town.—Dark-grey, fairly compact, even-bedded, with shale partings; used in the railway bridges and in the buildings of the neighbourhood.

Ederny.—Similar stone to that at Kesh; Market-house built of it.

Belleek.—At the Falls. Dark-grey, crystalline, compact, and close-grained; used in building Belleek Works.

Lisnaskea.—Dark-grey, good, sound, well-bedded stone, but

difficult to work with tools, owing to layers of chert in it. The Market-house and Railway Station are built of it.

Newtownbutler.—Bluish-grey, semi-crystalline, compact, earthy; Market-house built of it.

During the recent works for the drainage of Lough Erne they excavated into a dark compact limestone at *Belleek Ford*, which was used in the works thereabouts; while the new west bridge of Enniskillen is built of the stone quarried while cutting away the *Portora Ford.*

Some of the limestones are too earthy to burn into lime, but good strong lime is plentiful and cheap in the county, the best stones being procured westward of the lakes. A stone at Castle Caldwell gives a hydraulic lime.

GALWAY.

This county produces excellent limestones, suited for all cut-stone purposes, as they belong both to the older formations and to the Carboniferous. In the older formations (*Ordovician* and *Cambrian*), there are stones suitable both for tool-work and marble, in shades both of white and green. Those of green colours are unsurpassed elsewhere as marbles; but the whites, on account of their coarseness or other peculiarities, have not a forward place in the market. All these stones except the greens are more or less burnt for lime, some being better than others.

At Salrock, Derreennasliggaun, and Leenaun, in the north part of the county, there are *Silurian* limestones. Some of those at Derreennasliggaun are reddish, and have been used as a marble.

The *Carboniferous* limestones occupy all the eastern portion of the county, being nearly altogether either of the Calp or Burren types, principally the latter. Those of the Burren type are most conspicuous in the long tract that to the north enters the county from Mayo at Lough Mask, and extend southwards to Galway, and from that to the barony of Burren, Co. Clare. In these crags, in numerous places, superior rocks can be obtained; and the surface rocks in many places are worked; but necessarily they are not as easily tooled as in places where a quarry has been opened. They are of different shades of grey and blue, with subordinate black beds. From the latter some of the best black marbles in the world have been obtained.

The limestones of this portion of Galway, as also of the adjoining parts of Mayo and Clare, are so eminently suited for all cut-stone purposes, that now, as in former years, they are used to the exclusion of all other stones, although in the neighbourhood of the town the granites are unsurpassed in beauty, variety, and quality.

The great durability of the Galway limestone, and the delicate workmanship of which they are capable, are displayed in the various old ecclesiastical structures about the country, and also in the eleventh-century buildings in the town of Galway; which are still very perfect, notwithstanding the rough usage to which they have been subjected. Some of the pillars and other fine work in the Abbey of Knockmoyne, Ballyglunin, are still most beautiful.

The best stones of Ordovician and Cambrian ages are recorded at the following localities:—

Streamstown. About two miles north of Clifden.—Variegated and streaked green; worked for marble.

Creggs. About four miles east of Streamstown.—White to creamy white; and coarsely crystalline to compact and fine-grained; eminently suited for delicate cut-stone purposes, but cannot be procured in very large blocks; has been worked for marbles.

Clifden. In the vicinity are limestones.—Bluish-grey or dove-coloured; more or less schistose; and difficult to work.

Barnaoran.—The "Ballynahinch marble quarries," in the valley of the Owenmore. Green and variegated; worked for marble. The colours of the stone are very delicate and fugitive, which makes it unsuitable for any outside work.

Derryclare. Adjoining the lake.—White, or with a greyish tint; crystalline; compact; easily worked; but rises in unshapely blocks, which causes a waste in dressing. Was quarried some years ago by the Martins of Ballynahinch.

Lisoughter. Near the village, one mile from Recess.—Green and variegated; solely worked for marble.

Other stones of shades of green and white are already described in the lists of Galway marbles.

Of the innumerable Carboniferous limestone localities, the following may be specially mentioned:—

Galway.—To the north-east of the town, between it and Men-

lough, are extensive crags. The portion at the surface has been worked in different places, wherever the stone took the fancy of the stonecutter. A few quarries have been opened. Whitish to grey and blue, with subordinate black beds; crystalline; compact; fine-grained. Suitable for all kinds of cut-stone work; while the black beds are superior marble. It would appear as if a remunerative trade in their stone to England and elsewhere might be developed, as the limestone is of such excellent quality, while the freight ought to be low on account of so many ships, trading to the west coast, having to return in ballast.

Angliham and *Menlough*. About three miles north of Galway.—Worked for the marble beds.

Two-mile Ditch. Two miles from Galway.—Bluish-grey; crystalline; uneven-grained; easily worked.

Gortveragh. About one mile E. S. E. of Oughterard.—Dark-grey to black. Formerly worked by the Martins of Ballynahinch for marble. In this vicinity, and north-westward to Oughterard, there are good stones in various places suited for tool-work. A quarry was formerly worked in Creggs, from which good black stones were procured, one forming the flag at the hall-door of Lemonfield House, the seat of the O'Flaherties.

Arran Islands.—Great sheets of limestone of different shades of grey and blue; superior stone. On the north island, or Arranmore, some of the beds are of considerable thickness, and without joints for lengths of 150 feet to 200 feet or more, out of which great monoliths might be procured.

Newtown. Two miles from Gort.—Bluish-grey; close-grained; fossiliferous; works freely.

Ballyleigh, near Gort.—A fine black stone, formerly worked as a marble.

Castleboy. Between Gort and Loughrea.—Bluish-grey to grey; not difficult to work.

Craughwell. Seven miles from Loughrea.—Bluish-grey; an easily-worked stone.

Brackernagh, Ballinasloe.—Light to dark-grey; close-grained, crystalline; hard; an excellent stone; polishes well; can be raised in large blocks; worked as a marble; used very extensively in Dublin for all kinds of cut-stone purposes; carriage, in waggon loads, about 7*s*. 6*d*. per ton.

Workhouse (Ballinasloe).—Slight bluish-grey, crystalline, compact, hard; a good stone; difficult to work.

Kilroe.—Nine miles from Tuam. Bluish-grey; close-grained, semi-crystalline; splintering in fracture; works well. From here were procured the blocks for the cut stone for the R. C. Cathedral of Tuam.

Workhouse (Tuam).—Bluish-grey, crystalline, uneven-grained: smooth fracture.

Cong.—In the vicinity of Cong, in the counties Galway and Mayo, there are extensive crags of excellent stone, capable of being procured of any size, and the stones of some beds taking a good polish. It is suitable for all cut-stone purposes. The cut-stone work in the ancient abbey at Cong attests its durability, and the fine class of work it can be applied to. Some of these stones are capable of being split into long beam-like masses, suitable for bridges, for which purposes they have been used.

The Carboniferous limestone gives an excellent lime. The Silurian limestones at Salrock, Derrynasliggaun, and Leenaun, do not appear to have been much used, while the metamorphic limestones give a strong dark-coloured lime, but a small return. For this reason, in the west and north-west of the country Carboniferous limestone is generally procured either from the Arran Islands or from Clew Bay, Co. Mayo. In old times sea-shells were burned for lime along the Connemara coast.

Kerry.

The Carboniferous limestone occupies a considerable area in the eastern portion of the county, including a small isolated tract near Kenmare. It is of various characters, being cleaved or slaty near Kenmare, while to the north it partakes of the characteristic both of the Calp and Lower limestone, except at the Lakes of Killarney, where, in general, it is more or less slaty like that of Kenmare. This slaty stone was used in the building of the Abbey of Muckross, and furnished some very well-finished work. Limestone of Ordovician age occurs on Caherconree in the Dingle promontory.

In the Carboniferous the stones best known are as follows:—

Kenmare.—Grey and blue; slaty; difficult to work across the beds; can be made into good jambs, window-sills, and such-like, especially if sawn across the grain.

Lisaviggeen and Cahirnagher. About three miles from Killarney. —Grey, crystalline, even-grained, hard, but works well. These quarries chiefly supply Killarney with all cut and rubble stone.

Listowel.—Dark-grey, compact, earthy; works freely. This quarry has been largely worked for years, supplying stone to all the neighbourhood. The upper beds are a bad-class stone, but the lower are fit for any purpose, and with care can be raised of large sizes.

Ballinageragh.—Six miles west of Listowel. Dark-grey to black. Good for all cut-stone purposes. One bed black, mottled with white, was formerly worked for marble.

Rathos (Tralee).—A coarse, cherty stone, but useful for rough squared work.

Ballymacelligot.—About six miles from Tralee. Bluish-grey, close-grained; partly earthy; free-working; has been very extensively used in Tralee in the public and private buildings.

Good and cheap lime is made from the Carboniferous limestone. The Ordovician limestones of Caherconree, Dingle promontory, are also used for lime.

KILDARE.

Although most of this county is situated in the great Carboniferous tract of the central plain, none of the limestones that have been quarried are particularly well suited for cut-stone purposes, the best stones being procured near Celbridge and Leixlip, adjoining the Co. Dublin—stones that have been already described. Here, as elsewhere, all the quarries that have been opened are in stones of the Calp type, except those near Slade and Sallins, which, however, have been almost entirely worked for the purpose of being sent to the Dublin market for burning into lime.

Lime is very plentiful and good, the Calpy stone being in general burnt, or else boulders got in the Drift. At the Chair of Kildare there are Ordovician limestones, which are also burnt; but the lime from the Carboniferous limestone is preferred.

KILKENNY.

In Kilkenny there is a considerable area of Carboniferous limestone, the rock in many places being of a class fitted for all cut-stone purposes. The ordinary stone is usually in shades of dark-grey and blue, varying from close-grained to open-grained,

very tough, but working freely. It is very durable and strong, as exemplified in the different ancient buildings, as well as in the more modern structures. Almost everywhere it can be procured in whatever sizes may be required. Wyley has pointed out that, in Jerpoint Abbey and elsewhere, where a slight pillar had to support a great weight, limestone was used in place of sandstone. Associated with the ordinary limestone are creamy dolomytes. These have been, in general, ignored by the modern builders, but some of them, at least, are good and durable stones. In the base, and notably in the jambs, of the doorway of the Round Tower of St. Canice, Kilkenny (9th century), this stone was used, intermingled with sandstone. They have stood well; and, although showing the cavities so common in these stones, have not weathered. Most of a large flour-mill at Rockview, Inisnag, is built of this creamy dolomyte, from a quarry on the opposite side of the King's River.

Callan, Urlingford, Gowran, and Thomastown.—Quarries in the vicinity or neighbourhood of these different towns. Grey and blue limestones, suitable for all sort of cut-stone purposes.

Bonnetrath, Black Quarry, St. Kyran's, Templemartin, Archer's Grove, Sion House.—These quarries are all in the neighbourhood of Kilkenny, and give stones more or less favourable for cut-stone purposes. The Black Quarry and that at Sion House (now filled in) were quarried principally for the marble beds (see *Marbles*).

Ballykilaboy, Ballykeaghan, and Granny.—These quarries are situated in the south of the county, near Kilmacow and the River Suir; they are principally worked to supply stones to the counties Waterford and Wexford. Grey, crystalline, fine to coarse-grained; easily worked; take a good polish. The best stone can be procured at the first and second localities, and of large sizes—17 feet by 4 and 6 wide, and 2 feet thick. They have been extensively used in Waterford, as has also been the Granny stone, which, as it is situated on the bank of the Suir, and can be cheaply brought to Waterford by water, is utilized, notwithstanding its being of a flaggy nature and friable.

The lime made in this county is, in general, very good.

KING'S COUNTY.

Except in Slieve Bloom and in Croghan Hill, the rocks of this county are limestones, some being of excellent quality and well known.

Banagher.—In this vicinity the rocks are of the Calp type. Dark-blue or grey, inclined to black, earthy, in part flaggy, and difficult to dress; can be raised in large blocks suitable for coarse work, and were used extensively in the works for the improvement of the Shannon navigation; also in the buildings in the town and neighbourhood.

Skerough.—A mile from Birr or Parsonstown. Grey; compact, semi-crystalline; uniform in colour; easily worked; has been used very much in the public buildings of Parsonstown.

Clonmacnoise (Seven Churches).— Grey; thin-bedded; some beds very fossiliferous; weathers unevenly. Stones of large size, but modern thickness, can be obtained. This stone was very much used in the old buildings at Clonmacnoise, and in the works on the Shannon. The fossiliferous beds full of encrinite stems (locally called "screws") when polished have a quaint appearance, and have been much used for chimney-pieces, &c., having been formerly very extensively wrought at the Killaloe marble works. Wilkinson remarks, in connexion with the ruins at Clonmacnoise:—"In the doorway of one of these churches this stone has been used for delicate carving, and the surface of the door-jambs is polished, doubtless to display what was considered a beautiful material."

Upper Eglish.—Eighteen miles from Parsonstown. Grey, compact, easily worked. A great deal is sent to Parsonstown, being cheaper than the stone in that neighbourhood.

Killane.—Near Edenderry. Grey, compact, easy to work.

Ballydule (Tullamore).—Grey, with purplish tinge, crystalline, massive, thick-bedded, and can be obtained in large blocks. It takes a fine polish, and is then of a dove-colour, clouded with a darker tint. It is very much admired in chimney-pieces and ornamental slabs. This well-known and beautiful stone has been used in the tracery, windows, and dressing, in St. Patrick's Cathedral, Dublin; for columns and cornices of the Club-house, Kildare-street; the Roman Catholic Church, Monasterevan; and in numerous other places. Formerly more used in Dublin than

at present, the Ballinasloe stone having, in a great measure, taken its place. This seems to be due to the cheaper carriage of the latter stone.

Lime, in general, is very good and cheap in the King's County.

Leitrim.

Although a large portion of this area is limestone, yet this being, in general, of a calpy character, the best cut-stones are usually brought from the neighbouring counties. The caps on the gate-posts of the King's Demesne, near Drumsna, came from Ballinrobe, in the Co. Mayo. In the north portion of the county there are in some places very good stones, but no quarry of more than local note seems to be worked.

Mealwood.—Three miles and a-half from Carrick-on-Shannon. Greyish-blue; crystalline; compact; splintry; difficult to work: large blocks can be procured. Formerly this stone was much used, but of late better stone is brought from Hughes' Wood, in the Co. Roscommon.

Castleslavin. Three miles from Carrick-on-Shannon.—Whitish-grey, crystalline; fairly easy to work; retains its colour.

Ballinamoe.—The stone here similar to that at Mealwood.

Kilbride.—One mile from Drumsna. Bluish-grey; not very good for tool-work.

Lime in this county good; of superior quality near Manorhamilton.

Limerick.

More than half of this county is occupied by limestones of different qualities, the rocks being more distinctly and regularly grouped than elsewhere in Ireland, as previously pointed out (page 375). Margining the exposure of sandstone is the dark-blue, coarse, grey bedded Lower limestone, having over it the unbedded Fenestella limestone, and above that the Calp, ranging from a coarse slate and shale to marble; and above all, under the Coal-measure shales, the Burren-type rock.

Corgrig. A little S.S.E. of Foynes.—Dark-blue and grey, crystalline; in part earthy; works fairly well; flat-bedded; capable of being raised in very large blocks. Used extensively in pier-work on the Shannon, both in Clare and Limerick.

Askeaton.—The Fenestella limestones of this neighbourhood were used extensively in the old castle of the Geraldines, and in Askeaton Abbey. The beauty of the stone, its qualifications for cut-stone purposes, and its durability, are displayed in the ornamentation of the banqueting-hall of the castle and the windows of the abbey, but especially in the pillars of the cloisters. The latter are beautiful examples of carving, while at the same time they exemplify the fact that this stone is capable of taking a good and lasting polish. The exact place where these stones were quarried is not known; they are speckled greys, with tints of pink and dove-colour.

Kylethane (near Rathkeale).—Dark calpstone, inclined to blackish; in part shaley; hard, but works evenly except across the grain.

Churchtown (Newcastle West).—Dark grey. Works freely, but is very wasteful.

Drumroe.—Seven miles from Newcastle. A somewhat similar stone, but better than that at Churchtown, and generally preferred to it, but it is very brittle.

Ballycummin—About three miles from Limerick. Bluish-grey; works well.

Rosbrien.—Near Limerick. Very similar to last; a good stone.

Limerick.—*Thomond Gate.*—Greyish-black; fine, and close-grained; some of the beds formerly worked for marble of a superior quality. *Bridge quarry.*—Grey; compact; a good sound stone. *Carey's-road.*—Dark grey; semi-compact. *Gillogue.*—Blackish; very close-grained; good hydraulic lime. *Railway Quarry.*—Grey, black, and green. The black stone was worked for marble many years ago, and was good, being sent to the London market; the green is tuffose and arenaceous; works easily; friable; not durable; used extensively in the new railway station. The grey stones and those in the other quarries work more or less freely and well. They have been extensively used in Limerick and the neighbourhood.

Charleville.—Dark-grey; crystalline; compact; a free-working stone.

Quarry Hill, Knockany.—Four miles from Kilmallock. Greyish-blue; close-grained; very easy to work. It would appear from the nature of the stone that it was from these quarries that

the stones were procured to build the Abbey, and the Geraldine town of Kilmallock. In the latter, a few years ago, there were excellent examples of this ancient cut-stone work; but during the last twenty-five years nearly all these old structures have been removed.

The lime in this county, in general, is good; but that made from the Churchtown stone (Newcastle West) is poor in strength, and slacks slowly: the lime made from the Calp, near Rathkeale and Adair, is also poor.

At Robertstown, between Barrigone and Foynes, there is a stone that gives a good hydraulic lime, which was used at Askeaton Mills. In Gilloge Loch quarry, two and a-half miles north-east of Limerick, there is a good hydraulic limestone, which was used extensively during the building of the new dock at Limerick.

Londonderry.

This county is another of those in which there is very little Carboniferous limestone; it only being found in a tract between Maghera and Magherafelt. It is principally quarried for lime-burning, some of it being hydraulic.

Along the margin of the doloryte plateau, White Limestone appears in places, and is rather largely quarried, but principally for lime-burning, as its brittleness and jointy character make it yield unequally to the hammer, and unfit for fine tool-work. It can, however, be scabbled into blocks of small dimensions, which can be used in rough masonry.

In the hill-country, especially south and south-west of Dungiven, there are many beds of metamorphic limestone (Ordovician ?) quarried principally for lime-burning.

The principal quarry in the Cretaceous rocks is at—

Spring Hill (Moneymore).—White; very pure; hard; fissured and cracked. Cannot be raised in large sound blocks. Can be scabbled into blocks of small size. Extensively used in Moneymore when building the principal houses.

The quarries in the Carboniferous limestone are as follows:—

Desert Martin.—Bluish and brownish; rubbly; some beds yellowish-grey; solid; finely granular; crystalline, magnesian, and hydraulic. Used almost entirely for lime-burning.

Drumbally.—Very similar to the limestone at Desertmartin, and, as there, the yellowish rocks are hydraulic.

The limestones from the metamorphic rocks in the Tirkeeran Hills (south and south-west of Dungiven) give a good, strong, dark-coloured lime; while those of Carboniferous and Cretaceous age give purer and clearer products, and also yield a larger return.

At Desert Martin and Drumbally there are good hydraulic limestones, which were extensively used during the building of the bridges over the Bann, at Coleraine, Portglenone, and Toome.

LONGFORD.

Except to the northward, where the older rocks are exposed, this county is principally Carboniferous rocks. They, however, are nearly invariably more or less obscured by surface accumulations, such as drift and bog.

Lisryan. Four miles from Granard.—Dark-grey, earthy, compact; pyritous in places; principally in layers; partly shaly.

Crossrea. Near Granard.—Dark-grey; spotted when polished; coarse; in part fossiliferous.

Crewes. Three miles from Longford.—Light-grey. In the upper portion the beds are from 2½ inches to 3 feet thick, but the lowest bed is over 18 feet thick. From the 2½-inch bed flags 30 feet square or more could be procured. From the bottom, blocks 10 feet long and 6 feet wide can be raised. The stone is very highly thought of, and was used in the building of Carrickglass House.

Richmond Harbour. Five miles from Longford.—Greyish-blue; can be raised in very large blocks. Used extensively in the Shannon works at Tarmonbarry.

Rathcline. Near Lanesborough.—Dark-grey; compact; works freely and polishes well. It was used largely in the works on the Shannon in the vicinity of Lanesborough.

The lime of this county is generally good.

LOUTH.

A very small extent of Carboniferous limestone is found. It occurs in the valley of the Boyne, at Ardee, north and north-east of Dundalk, and near Carlingford.

Greenore and Carlingford.—Bluish-grey. Extensively quarried

to supply the south portion of the Co. Down and Dundalk with lime and cut stone. In some beds very large blocks can be raised; principally quarried for lime; not very good for tool-work.

Kilcurly. Two miles from Dundalk.—Greyish-blue; compact; crystalline; works freely.

Ardee.—Dark-grey; semi-compact; difficult to work.

Drogheda.—Dark greyish-blue, inclined to black; earthy; compact; in part shaly. The old buildings in which it has been used are very much weathered.

Sheephill. Three miles from Drogheda.—Light bluish-grey; crystalline; compact; works freely. A very good stone, very unlike any other in the county, being more like those at Lough Sheelin, in the Co. Meath (Ross Castle). It has been used in some of the public buildings in Drogheda, and extensively in the adjoining portion of the Co. Meath, and in the restoration by Mr. Roe of Christ Church Cathedral, Dublin.

Lime strong and good, but dark-coloured.

Mayo.

As in the adjoining county of Galway, there are here also extensive crags or sheets of bare limestone, especially in the neighbourhood of Lough Mask; and the good quality of the limestone has prevented other stone being wrought or even looked for.

Cong and Ballinrobe.—In various places in the neighbourhood of these towns, varieties of grey and blue; crystalline; compact; sound; works easily; splits easily; can be raised in very large blocks; suitable for all kinds of cut-stone purposes.

Westport.—Two quarries in the vicinity, the larger called *Farm Quarry*. Greyish-blue; very good quality; bedded from 1½ to 2 feet thick. At the Farm Quarry there is a clearing of about 20 feet of soil and 16 feet of bluish sandstone. A peculiarity of the limestone is the occurrence of invisible joints, called "threads" by the quarrymen. These do not detract from the value of the stone, as it does not weather, nor, when in work, do the stones crack along them. They are of great use to the workmen, as by experience they have learned that, if they throw water on the face of a bed, they can see the "threads" when it is drying off, and subsequently, by the judicious application of the wedge, they can readily split the stones.

Wakefield, or Black Quarry (Castlebar).—Dark-grey or blackish, of the Calp type; very coarse; can be scabbled, but not fine-worked; very large blocks can be raised.

Moneen. One mile from Castlebar.—Bluish-grey; fairly easy to work; was used when building the gaol and infantry barracks.

Crossmolina.—Dark-grey to blackish; compact; dense; earthy. It is quarried near Rosserk Abbey, which was partly built of it. Wilkinson points out that it is not a stone to be recommended, as it is brittle, and liable to break off when in work, which, he points out, can be seen in the windows and doorways of the Fitzgibbons' Castle, a few miles north of Castlebar, where a similar stone was used.

Ballina.—In this neighbourhood the stone is very similar to that of Crossmolina.

Moyne. Seven miles from Ballina.—Dull-grey; has an irregular fracture, but can be worked in any direction, and can be procured in very large blocks. A superior stone for any cut-stone purposes. It occupies a considerable area between Rosserk and Killala, the latter town being built on it; it also occurs at Moyne Abbey. The durability of the stone and its excellent qualities are exhibited in the Round Tower of Killala, the Abbey of Moyne, and the cut-stone in Rosserk Abbey. This stone was also used in the mansion of the Knox-Gores, near Ballina, and for cut-stone in the Roman Catholic cathedral.

Excellent lime is made from the Carboniferous limestone; also from boulders in the Drift. A Silurian limestone near Toormakeady is said to be hydraulic. Near Cong there is a clay which, if mixed with lime, makes it hydraulic; used extensively at Cong in the river works, and at Lord Ardilaun's fountain.

MEATH.

Carboniferous limestone occupies the principal part of the county, but it is divided into north and south districts by a tract of arenaceous and slate rocks. The stones in the southern district partake very much of the Calpy nature of the rocks in the Co. Dublin, while very superior stones are procured in the northern division, the quarries of Ardbreccan and Rosscastle, or Cashel, being extensively known; also the neighbouring quay of Crossagh.

Ardbreccan. Three miles from Navan.—Brownish-grey; when dressed, grey, very crystalline; works very freely; can be obtained of very large sizes; a very superior working-stone. Has been extensively used at Navan, Trim, Kells, Slane, and elsewhere—even at great distances.

Crossdrum.—Two miles west of Oldcastle. Whitish-grey; very pure; works freely. Can be obtained in blocks of large sizes.

Rosscastle or Cashel.—Seven miles from Oldcastle, close to Lough Sheelin and the mearing of the county; a very superior stone and in much request. It is like the Crossdrum stone, but of a finer texture and lighter colour; is extensively used in this county and in Cavan and Longford, the columns in the R. C. Church of the latter having been procured there. It was also used in the building of Loughcrew House.

Crossagh, near Rosscastle.—The stone is very similar, but coarse: yet it is more preferred by the builders in Dublin.

Trim.—Dark-blue to blackish; of the Calpy type; earthy, but compact; even-bedded; a good workable stone for plain building, but will not dress well. Has been used in most of the public buildings in Trim, also in the old Norman castle and ecclesiastical structures; but in the latter sandstone has been employed where cut stone was required.

Drogheda.—Near Drogheda the stone is, in general, grey and brittle; but to the eastward it is dark-grey to blackish; of a Calpy nature, and can be raised in very large blocks suitable for rough work. Large quarries were opened at the east margin of the town, from which were procured the stones to build the Boyne Viaduct; the dressing and cut-stone work being brought principally from Ardbreccan or Milverton, near Skerries, Co. Dublin. Farther eastward, adjoining the river flats, there are the Corporation quarries, from which were procured the stones for the extensive harbour improvements.

Lime very good; made from the Carboniferous limestone and from the boulders in the drift.

MONAGHAN.

The limestone is of Carboniferous age, and is generally of a Calpy nature, not suitable for tool-work. Some of the best stones in the

neighbourhood of Clones and Monaghan are situated in such low ground that they are liable to be flooded, and are, therefore, too expensive to work. The best quarries suitable for cut-stone purposes are in the neighbourhood of Carrickmacross.

Barley Hill. Five miles from Carrickmacross.—Dark bluish-grey; hard; well suited for tool-work, but rather difficult to work.

Lime good, but often dark-coloured.

QUEEN'S COUNTY.

Carboniferous limestones occupy the central portion of this county. In some places the stone is of very good quality, but in others it is inferior, being of a Calpy type.

Stradbally.—Light brownish-grey to grey; close-grained; well suited for cut-stone purposes. Has been largely used in this and the neigbouring county of Kildare. In all the public buildings at Maryborough it has been used; also at Monasterevan and elsewhere.

Dunamase. Two miles from Stradbally.—Grey; compact; slightly splintery; but otherwise a good stone.

Spire Hill.—Five miles from Mountmellick. Grey; oolitic; slightly silicious; does not work freely.

Thornbury (Abbeyleix).—Dark greyish-blue; silicious, and difficult to work.

Ballyullen. One mile from Abbeyleix.—Greyish-blue. This is kinder and more easily worked than the Thornbury stone, and is more generally used in Abbeyleix.

Portarlington.—Good stone for rough work; quarried in different places, but not approved of for tool-work.

Graigue. On the edge of the county, a suburb of Carlow.—The quarries here were principally worked for marble. The associated stones being burnt for lime.

Lime very good, cheap, and abundant.

ROSCOMMON.

Nearly the whole of this county is occupied by Carboniferous limestone, only some very subordinate tracts of older rocks appearing up through it. The rocks are very varied in character, from bad Calpy stones to those of the Burren type. There are, however,

dispersed over the county, many quarries capable of producing a good class of stone.

Crisnagh. Near Boyle.—Grey; semi-compact; crystalline; works well and freely.

French Park. Near Boyle.—Grey; close, and compact; a free-stone; works well. The quality of the stone near Boyle, and its suitability for tool work, were not formerly recognised. When Rockingham House was built, the stones were brought sixteen miles from Ballinafad, Co. Sligo. Some of these stones polish well, and are used for tombstones.

Hughestown. A few miles from Carrick, near the Shannon.—Light greyish-blue; some of a better class become of a lighter colour when worked. This stone has been used in Carrick-on-Shannon in preference to the stone at Mealwood.

Castlereagh.—Between this town and Boyle there are different quarries; but the stone is more or less of a Calpy nature, and difficult to work. Mount Sandford House, near Castlereagh, was built of stone brought from Bellanagore, about nine miles distant.

Bellanagore. Seven miles from Elphin, the quarries being situated a few miles to the west and south-west of the village.—Dark to light grey; much freer than the stones near Castlereagh; but inferior to those near Boyle.

Aughris. About two miles from Roscommon.—Dark to light grey; fine; crystalline; works freely.

Scardaun. About four miles from Roscommon.—Dark to light grey; works freely; in character very like those of the barony of Burren, Co. Clare.

Lecarrow (Knockcroghery).—Grey; finely crystalline; regularly bedded; in parts cherty; works fairly well.

Taghmaconnell.—In this stony district the rocks are of types similar to those in the barony of Burren, Co. Clare. Good stones might be procured, but no quarry of note has been worked, as the stones needed in the neighbouring towns of Athlone and Ballinasloe are more easily procured at the latter, in the Co. Galway, and at Clonmacnoise, in the King's County.

The lime in this county is excellent and cheap.

Sligo.

In this county, as in Mayo and Galway, there are extensive crags and cliffs of Carboniferous limestone. The rock, however, is not, in general, as good a class of stone; those about Lough Arrow, to the south, and some beds near Ballysodare, being considered of the best quality. Many of the Sligo stones are more or less of a Calpy type, and difficult to dress; yet in the old abbey at Sligo the local blackish stone was used for all purposes; and in the ruins are different examples of excellent work still in good preservation; but of late years the Killea sandstone, Co. Leitrim, seems to have been preferred for cut-stone purposes.

Ballysadare.—Greyish-blue; crystalline; semi-compact; easily worked; takes a good polish; has been used for tombstones.

Ballinafad. On the south-west shore of Lough Arrow.—In different places, grey and blue; crystalline; semi-compact; easily worked. Formerly much used before the quarries at Boyle, Co. Roscommon, were opened; the stones for Rockingham House, near Boyle, having been brought from this neighbourhood.

Lime of the county good and cheap, but often dark-coloured.

Tipperary.

Except in portions of the barony of Lower Ormond, where it is of the Calp type, the limestone of this county is of a very uniform blue colour, and compact. It has been very generally used in some of the best ancient ecclesiastical structures. On this subject Wilkinson writes:—"At Cashel, with the exception of the sandstone used in the construction of Cormac's Chapel and the Round Tower, limestone is the material with which all the buildings have been erected. At Holycross this stone has been used; and the beautiful ruins in both these places show the excellent quality of the stone, both as regards the fine work it is capable of receiving, and its durability; for the mouldings of the oldest parts are still fresh and sharp on the edges, and even preserve the marks of the tools used in preparing them."

Fir Quarry, Ballinderry. Not far from Carrick-on-Suir.—Grey; close; even-grained; difficult to work.

Camus. A short distance from Cashel.—Light-grey; easy to work.

Lewagh (Holycross). A little north of Thurles.—Dark-grey; semi-compact; a very superior stone for all fine work. This appears to have been the stone with which Holycross Abbey was built.

Castle Meadow. One mile from Thurles.—Grey; free working; very good for dressed work.

Ballinacurra. Four miles from Clonmel.—Dark greyish-blue: coarse and earthy beds; rather difficult to work, and more suitable for rubble than dressed work.

Lisbunny. Near Nenagh.—Dark-blue, compact; earthy; in general not difficult to work. Some beds are more argillaceous than calcareous.

Loughalton. Two miles from Nenagh.—Dark-blue to blackish; some beds lighter, and greyish; works easily.

Loughorne. Three miles from Nenagh.—Variable in colour; shades of light-grey, dark-grey, and blue; in general compact; the blue stones very earthy; works easily.

Ballinillard. Near Tipperary.—Greyish-blue. A light-coloured magnesian limestone lies below the blue; works well.

Portland.—Near to Portumna Bridge. Dark-blue to blackish; earthy; in part shaly; large blocks can be raised. Used extensively in the works on the Shannon. In this portion of the barony of Lower Ormond the rocks are of the Calp type, and are not in general suited for cut-stone purposes.

In general very good lime; some dark-coloured. Some of the Calp beds either will not burn, or will do so with difficulty.

Tyrone.

In this county are found Cretaceous, Carboniferous, and Metamorphic limestones. The White Limestone (Cretaceous) occurs to the north-east, near Coagh and Stewartstown; the Carboniferous occupies more or less scattered and semi-detached tracts; while the older limestones are found in bedded masses among the metamorphosed rocks of Ordovician and Cambrian (?) ages in the north-west of the county. Dolomyte, containing Permian fossils like those at Cultra, Belfast Lough, Co. Down, has been found at Tullyconnel, near Ardtrea, a mile to the west of this place; and in sinking a coal-pit at Templereagh, adjoining the Annaghone colliery.

These Permian rocks have not been utilized. The Cretaceous are used principally for lime-burning, and so are also the Metamorphose limestones, and in a great measure the Carboniferous. Limestone is not, in general, used for cut-stone purposes, as sandstones of excellent qualities occur in different places, and they are usually preferred.

Cookstown. At Railway Station.—Various shades of grey to pink and red; fossiliferous; crystalline; some beds compact, and take a good polish. In beds from an inch to 4 feet thick. A little east of the town is a limestone of a purplish-grey colour; compact; crystalline; works fairly.

Broomhill. A mile north of New Mills.—A bed of hydraulic limestone; 12 feet thick proved by boring.

Drumreagh. Three and a-half miles north-east of Dungannon.—A thick bed of close-grained blue hydraulic limestone; under 37 feet of thin-bedded rock.

Keeran's Cross. Three miles south-east of Pomeroy.—A thin bed of light-brown hydraulic limestone.

Castlecaulfield.—Three miles west of Dungannon. Grey; compact; crystalline; in places flaggy, or with shaly partings between the beds; works fairly well.

The Carboniferous limestone, in general, is impure and hard to burn, or gives a dark-coloured lime; but at Cookstown an excellent white lime is produced.

The White Limestone in general gives a rich lime.

In the granite to the north-west of Pomeroy, at Limehill, there is a peculiar compact white limestone burned for lime, but not of a good quality.

Hydraulic limestones, as above mentioned, are found at Broomhill, Drumreagh, and Keeran's Cross.

Waterford.

The Carboniferous limestone occurs nearly altogether in long east and west basins—one in the Youghal valley, and another in that of Dungannon, with a small tract in the valley of the Suir. The limestone used in this county for dressed-stone purposes is principally brought from the south portion of the county of Kilkenny, being procured in the quarries in the neighbourhood of Kilmacow.

Whitechurch. South of Cappoquin.—Light-grey; hard; difficult to dress; has been used in the town of Dungarvan, five miles distant; also in the railway and other bridges.

Shandon (Dungarvan).—Dark-grey; not good for dressed-work; much inferior to that of Whitechurch, but more easily dressed; used in building the Courthouse; gives superior lime.

Oughboy.—A mile from Lismore. Light-grey; hard, but brittle; coarse; easy to work.

Between Lismore and Dungarvan there are in places small quarries, where fair stone for tool-work has been procured. Some beds take a good polish, and have been used as marbles.

Dunkitt.—Here, and also on the north side of the Suir (Co. Kilkenny), limestone has been extensively quarried, to be sent down the Suir and up and down the Barrow, to supply the counties of Wexford, Kilkenny, and eastern Waterford, with stones for lime-burning. It is a thin-bedded, shaly, earthy stone; but as it can be cheaply carried by water to Waterford, it has been very extensively, though not always advantageously, used there.

Good lime, but dark-coloured in general.

Westmeath.

Except in a few isolated places, Carboniferous limestones occupy the whole of this area. The rock is, however, comparatively speaking, seldom seen; and when it comes near the surface it is usually of the Calp type; or of a character unsuitable for cut-stone material. For this purpose limestone is principally obtained from Clonmacnoise, King's Co., and Ballinasloe, Co. Galway, and formerly from Rosscastle, Co. Meath. A good stone, also used as a marble, occurs near Moate, while others have been extensively quarried about Mullingar, and used in that town: the stones, however, near Mullingar do not give fine or durable work.

Hall. Three miles south-west of Moate.—Grey, with splashes of white and red: of good quality, worked as a marble; extensively used in the new Exchange, Manchester, and in other places in England.

Bunbrosna and *Multyfarnham.*—Dark-blue to blackish; even-bedded. Various quarries, at which the stones are principally raised for rubble work and flagging.

Pakenham Hall. A mile from Coole.—Dark-grey; crystalline; fossiliferous; earthy; a fair stone.

Kerry. Three miles from Mullingar.—Dark-grey to blackish; compact; earthy; in part shaly; works freely; used in the Catholic Church, Mullingar.

Fulmore.—Seven miles from Mullingar. Dark-grey to blackish; Calp type. Large stones can be raised, which were used in the Railway Works and Mullingar.

Lime good, but dark-coloured. Hydraulic limestone occurs at Donore, where other beds give a very good lime.

WEXFORD.

In this county there is very little Carboniferous limestone, as it only occurs near Wexford, in a strip running south-west from the south of the harbour to the sea, near Duncormick, and in the promontory of the Hook. It is not much used for building purposes, although formerly much quarried for lime-burning. It is more or less of the Calp type, and not well suited for cut-stone purposes. Large blocks can be raised, and the stone from the Drinagh quarries, south of Wexford, were used in the construction of the new pier at Ballygeery in the South Bay. The quays also, and other buildings, have been built from similar stones, procured here or in the quarries in the neighbourhood. The limestone at Drinagh is in part hydraulic.

In the Ordovician rocks there are beds of limestone and calcareous tuffs. The limestones are used principally for lime-burning, especially one bed near Courtown Harbour, which is in part hydraulic. The tuffose limestones dress easily, and have been used in the railway bridges, but they do not appear to be durable.

Good strong but dark-coloured lime from the Carboniferous limestone; the Ordovician limestones also give strong dark-coloured lime, but not good returns. In old times, even at considerable distances from the coast, sea-shells were burnt into lime.

Hydraulic lime can be made from some of the beds in the Drinagh quarries, while a poorer hydraulic limestone occurs at Courtown.

Wicklow.

This is the only county in Ireland in which Carboniferous rocks have not been found; nor is it likely that any outlying patches occur under the superficial accumulations. It was also generally believed that no limestone of any kind exists; but of late years this has been proved to be incorrect.

In the Glenart demesne, near Arklow, to the westward of the Castle, there is a very impure thin bed of limestone. Westward of Castlemacadam, near the church, in the brow of the hill, there are beds of flaggy limestone, which seem to have been worked to a small extent in former times; and to the north-east this limestone again appears in the brow of the hill, west of the Ovoca railway station. A bed of limestone was cut in the Avonmore valley when driving up the level from the old Glebe to Connery mine; while limestone also occurs near Westaston, some few miles eastward of Rathdrum. None of these limestones have, at least in late years, been quarried; but they appear to be of a quality very similar to the Courtown limestone, Co. Wexford.

XXXVII.—ON A PECULIARITY IN THE NATURE OF THE IMPRESSIONS OF *OLDHAMIA ANTIQUA* AND *O. RADIATA*. By J. JOLY, B.E., Assistant to the Professor of Civil Engineering, Trinity College, Dublin.

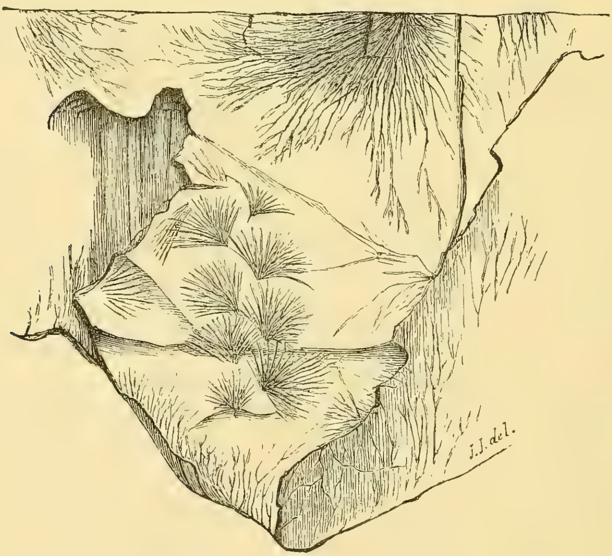
[Read, November 17, 1886.]

Recently, while examining some fragments of slate from Bray Head showing marks of Oldhamia, I noticed that on such specimens as displayed both varieties of marking, *O. antiqua* and *O. radiata*, the following peculiarity appeared:—A sunken or depressed delineation of one variety accompanied a raised or relieved delineation of the other variety. Thus, if on any specimen *O. antiqua* appeared as a depression, on that same surface the *O. radiata* appeared in relief. I verified this relation over such specimens as were in my possession, twelve in number, collected by myself at various times from certainly not less than two distinct localities on Bray Head: one of which is the well-known locality close to the Periwinkle Rocks. These specimens are on the table.

From this observation it appeared probable, if any meaning was to be attached to the relation, that a further relation would be found to obtain between the mode of delineation and the position in the rock. This was easy of investigation, as such further relation might be sought for wherever either variety of mark was to be found *in situ*. Examination revealed the expected relation, in this order:—On the upper surface, or what was most probably the surface of deposition (the cleavage of the Cambrian slate of Bray Head coincides generally with the plane of bedding), the *O. radiata* appeared invariably as a depression, the *O. antiqua* in relief. In four localities this was verified. In one only, at the south entrance to the new tunnel, was there any doubt. Here the folding is so extensive and complicated that it was uncertain what surface was uppermost, and the marks also were obscure. Close to this fifth locality clearer marks on less contorted beds are in accord with the relation. It is apparent, indeed, that in the event of the relation being more extensively verified, it might in such cases be applied to determine whether or not inversion had occurred.

An explanation of this peculiarity—which at all events evidently obtains extensively in the Bray Head rock—is not easily offered; but I think the polarity of the marks respecting the plane of deposition is of importance in this, that it establishes a relation between the phenomena giving rise to them and that plane. Thus, for example, any hypothesis ascribing their origin to something in the nature of crystallization of the materials of the rock must account for a direction of cleavage differing in the two varieties respecting the plane of bedding. This would appear to render a frost-mark theory (these *Proceedings*, *antea*, p. 156) inadequate to explain both forms, although the polarity in the case of the *O. radiata* would accord with the theory. On the other hand, it need not necessarily, I think, be opposed to an organic origin for both forms.

It is observable that if fragments be peeled off the slate, it is often found that the marks have been transmitted, or extend, to layers beneath, so that lines on the upper are seen as continued on



the adjacent lower surface; this, too, for thicknesses exceeding a millimetre.

The accompanying woodcut recalls the appearance of a surface

from the Periwinkle locality. It is seen that it is not quite a plane surface, but one which has developed somewhat conchoidally. It is rough, too, and unlike the usual bedding surface. Nevertheless the *O. antiqua* branches over the ridges without sensible loss of distinctness, and undeviated. This is not an uncommon case. The specimen in question shows the *O. antiqua* in relief, the *O. radiata* depressed. The specimen has been placed in the Science and Art Museum, Kildare-street.

XXXIX.—CURIOUS CONSEQUENCES OF A WELL-KNOWN DYNAMICAL THEOREM. By G. JOHNSTONE STONEY, M.A., D. Sc., F.R.S., a Vice-President of the Society.

[Read, January 19, 1887.]

There is a well-known theorem in the science of Dynamics, relating to a system of bodies in motion, which may act on each other, but are not acted on by any external force. The theorem in question is, that if at any instant the velocities of the several bodies of the system be reversed, without any other change being made (*i. e.* without altering either their masses or the laws according to which they attract or otherwise act on one another), then will all the bodies of the system retrace their steps, traversing in the reverse direction the same paths which they had previously described, and in such manner that any position through which any one of these bodies had passed in its onward progress, at a certain time before the reversal, will be repassed with the same velocity, but in the opposite direction, at the same interval of time after the reversal.

Now, if we regard the universe as a dynamical system, it is exactly such a dynamical system as this theorem presupposes. Its several parts act on one another, but are not subjected to any other forces. And it is of interest to study what would be the result if such a reversal as the theorem supposes were to take place throughout the whole universe. We must, of course, suppose that the reversal affects all the motions of the universe, not only its molar motions, but its molecular motions also; and not only the motions of its ponderable matter, but also the motions of the ether.

In order to be in a position to study the effects, let us first suppose that we are spectators of this far-reaching change, without being ourselves affected by it—that we are, from an intellectual standpoint, as it were outside the great system whose future history we want to trace, simply observing everything that takes place, and not in any way interfering with it, nor ourselves in any way transformed by the change.

To such a spectator the past history of the universe would repeat itself in reverse order, and many of the conditions under which it would do so would appear to him very strange. The bird which was shot to-day by the sportsman, and which is now lying in his kitchen, will, if the reversal of the universe were to take place at this instant, be restored by the keeper to the game-bag, will be carried by him, walking backwards, to the place where the pointer had fetched it in, where he will take it out, and lay it on the ground. Thence the dog will lift it in his mouth, and, trotting backwards, will reach the spot where the bird fell, where, however, it will now rise to the height at which it was shot, from which it will fly away backwards unharmed. Meanwhile, the vapours into which the powder had been dissipated will stream back into the barrel of the fowling-piece, and condense themselves again into gunpowder, while the grains of shot will rush towards the muzzle of the gun, and crowd into its breach.

It is of importance to observe that, under the new conditions of the universe, all true dynamical laws will remain the same as at present, but many quasi-dynamical laws will be reversed. Thus, the first law of thermodynamics—the law of the equivalence of energy—will remain unaltered, but the second law will become its converse. Instead of a warmer body tending to impart heat to a cooler body, as at present, the new condition of things will tend to make their temperatures more divergent. Heat will become mechanical energy directly, and without requiring the accompanying degradation of energy which now takes place. Friction, instead of retarding the progress of bodies, will help them forward. The air, instead of impeding a missile passing through it, will urge it on. And, when reviewing a system so divergent from what we find in the actual universe about us, it is very instructive to bear in mind that *the universe, under the new conditions that we suppose, would be as perfect a dynamical system as the actual universe is.* This places before the mind in a very strong light the grave error which is too often made when such laws as I have referred to—the second law of thermodynamics, &c.—are supposed to be true dynamical laws.

This naturally leads up to the consideration whether the laws of causation would be affected. Those relating to true causes would not be affected: those relating to quasi-causes would all be

inverted. True causes never precede their effects; they are always strictly simultaneous with them. The science of Dynamics recognises true causes only. All change of the motion of a body is in that science attributed to forces acting *while* the change is taking place; and the persistence of a body in motion while no forces are acting on it is due to the inertia of the body, *i.e.* the body itself is the cause of it. It is because the inertia of a body is a sufficient cause for its continuing in motion that time can elapse between events in nature. Whether the motion changes or does not change, the effect and its true cause are accurately simultaneous. The dispute as to whether action takes place at a distance does not disturb this statement. Everyone who does not suppose that the sun attracts the earth from a distance and without lapse of time, supposes that some medium pervading the intervening space communicates the action; and it is not the distant body, but the surface of this medium where it touches the body acted on, that upon this view can alone be recognised in the science of Dynamics as the true immediate cause of the changes of motion of the second body. Thus, in all cases, dynamical effects arise along with, and not after, their causes. But in popular language, and indeed in all but very carefully strict language, many events are spoken of as caused by events that have preceded them. Thus, in the usual loose way of talking, we may speak of a ball's having been reacted on by the ground as the cause why it is now ascending, although a moment's reflection would show that, in strict language, the reaction of the ground has caused only those changes of motion that occurred while the ground was pressing against the ball, and that the ball's afterwards continuing to ascend is due to its inertia. Sometimes the two classes of causes are distinguished as immediate and remote. Now the change which we have supposed the universe to undergo would in no way affect immediate, that is, true causes; but all that we now recognise as an antecedent or quasi-cause would, to the spectator looking on at the universe from without, be changed into the effect, and that which is now the effect would to his apprehension occur first and become the cause.

These seem the first lessons which the study we have entered upon impresses upon us. But it is capable of giving further instruction. Hitherto we have supposed the altered universe looked

at by a spectator who was himself unaffected by the change. But we are all ourselves parts of this universe, and the series of thoughts that occur in our minds are quite as much events that happen in the universe as the motions we see around us. Such a reversal of all the velocities of the universe as I have supposed, if it really took place, would affect us and the motions in our brains as well as everything else in the universe; and we have now to consider what the effect of this would be, and how it would modify our observation of what is going on around us. From the instant of the supposed reversal, the thoughts which had occupied our minds previous to it will recur, repeating themselves backwards, just like every other event in the universe. The memory of having eaten our breakfast will present itself first; the sensation that we are eating it will come on afterwards: at least this is the order in which we must as yet describe these thoughts in our mind as occurring; it is the order in which they would appear to that outsider whom we before supposed to be surveying the universe. But the relation of the one thought to the other *in our own mind*—of the memory to the sensations remembered—will be after the reversal exactly the same[1] as it was when these same thoughts occurred before in their right order. Now, TIME IS ONLY AN ABSTRACT TERM REFERRING TO ALL SUCH RELATIONS, just as mankind is an abstract term referring to the individuals that are men. And just as it is individual men who have a real existence, and not mankind in the abstract, so is it the individual time-relations occurring between real thoughts or real events that have a real existence, and not time itself, which is a mere word. But as we have found that the time-relations between our thoughts after the supposed reversal are absolutely the same as the time-relations between these same thoughts when they occurred before the reversal, then to us, if we share in the reversal, our thoughts and the events in the world about us will seem to occur in the same order of time as they did before the reversal, and *the moment of reversal will in both cases appear to us to occur last in point of time.* In other words, our supposition of the reversal of all the motions of the universe, when it

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[1] In fact, the time-relation between the two states of mind amounts to this, that a part of the one state of mind is a memory of the whole, or of a part, of the other state of mind; and this is equally the case after as before the reversal.

embraces the whole universe, ourselves included, does not really involve a repetition of the events in reverse order, but only a second way of reviewing the past history of the world.

These considerations do not seem altogether unfruitful. They emphasise the distinction between true and quasi-dynamical laws, they clear our thoughts with reference to the relation of cause and effect, and, above all, they help to dispel from our minds the prevalent error that time has an existence in itself independently of the particular time-relations that prevail between the thoughts that really occupy our mind, or between events[1] that actually occur in the universe about us, or between those events and our thoughts. In reality, the aggregate of these individual time-relations is *the whole* of what exists in nature as a background for our conceptions about time.

[1] Thoughts in other people's minds are some of the events that occur in the universe about us; that is, in the rest of the universe, excluding ourselves.

XL.—THE PHENOMENA OF SKATING AND PROFESSOR J. THOMSON'S THERMODYNAMIC RELATION. By J. JOLY, B.E.

[Read, December 15, 1886.]

Professor J. Thomson's Thermodynamic Relation

$$\frac{dt}{dp} = \frac{T(v_0 - v_1)}{L}$$

entails that in the case of a substance such as ice, in which the consequence of the transference to the substance of a quantity of heat, L, is to produce a negative change of volume, the value $\frac{dT}{dp}$ is negative, and a lowering of the melting-point, results from the application of pressure.

I would suggest that to the many phenomena which have found an explanation in this physical fact might be added those attending skating, *i.e.* the freedom of motion, and, to a great extent, the "biting" of the skate.

The pressure under the edge of a skate is very great. The blade touches for a short length of the hog-back curve, and, in the case of smooth ice, along a line of indefinite thinness, so that until the skate has penetrated some distance into the ice the pressure obtaining is very great; in the first instance, theoretically infinite. But this pressure involves the liquefaction, *to some extent*, of the ice beneath the skate, and penetration or bite follows as a matter of course, the amount of penetration being roughly a measure of the extent to which liquefaction obtains. As the blade sinks an area is reached at which the pressure is inoperative, *i.e.* inadequate to reduce the melting-point below the temperature of the surroundings. Thus, estimating the pressure for that position of the edge when the bearing area has become $\frac{1}{50}$ of a square inch, and assuming the weight of the skater as 140 lbs., and also that no other forces act to urge the blade, we find a pressure of 7000 lbs. to the square inch, sufficient to insure the melting of the ice at $-3{\cdot}5°$ C. With very cold ice

the pressure will rapidly attain the inoperative intensity, so that it will be found difficult to obtain bite—a state of things skaters are familiar with. But it would appear that *some* penetration must ensue. On very cold ice, "hollow-ground" skates will have the advantage.

This explanation of the phenomena attending skating assumes that the skater, in fact, glides about on a narrow film of water, the solid turning to water wherever the pressure is most intense, and this water, continually forming under the skate, probably resuming the solid form when relieved of pressure. From the thermodynamic point of view, the skater is the external agent, putting the ice through a reversed Canot's cycle. Fluid shearing takes the place of solid friction, and as the resistance thus arising is proportional to the area over which shearing obtains, that temperature at which the skater just obtains the requisite bite to impel himself will be the most conducive to freedom. Other phenomena, such as tearing and crushing, doubtless attend the skater's motion, but such must necessarily be detrimental to freedom; indeed, the fact that such phenomena do often attend the easy motion of the skater might be regarded as evidence against the popular notion that the possibility of skating is to be ascribed solely to the *smoothness* of the ice. It is quite certain, I think, that skating on so smooth a substance as plate-glass, for example, more expecially if accompanied with incidental tearing of the surface, would be quite impossible. Again, it is observable that skating on very *rough* ice is possible. Only, indeed, when the phenomena of solid friction give place to those attending the motion of lubricated surfaces is there at all a comparable degree of freedom. Walking on a pavement greasy with fine mud occasionally recalls the accidental treading on a "slide."

In the expression "as slippery as ice" there is revealed a consensus of opinion as to the abnormal nature of ice respecting friction.

XLI.—ON THE ANTIPODAL RELATIONS OF THE NEW ZEALAND EARTHQUAKE DISTRICT OF 10TH JUNE, 1886, WITH THAT OF ANDALUCIA OF 25TH DECEMBER, 1884. By J. P. O'REILLY, C. E., M. R. I. A., Professor of Mining and Mineralogy, Royal College of Science, Dublin. (Plate IX.)

[Read, January 19, 1887.]

In an address delivered before the Royal Geological Society of Ireland on the gaseous products of the Krakatoa Eruption, I took occasion to call attention to the antipodal relations of Java with the north-west coast of South America, and argued from the fact of there being, in this case, two districts of marked seismic activity directly antipodal, that in cases where such relations exist, marked seismic action may be expected to manifest itself. I had, in another Paper read before the Royal Irish Academy 14th November, 1881, argued that in centres affected by earthquake action the points of greatest activity generally lie on coast lines, or on the boundary lines of geological formations: this was subsequently illustrated by an earthquake map of Great Britain and Ireland, annexed to the catalogue of earthquakes having occurred in these countries, submitted to the Royal Irish Academy, 28th April, 1884.

The antipodal relations above referred to, as also the connexion of earthquakes therewith, and with coast lines and coast line directions, have recently received a remarkable illustration in the great earthquake of Andalucia of Christmas, 1884, and January, 1885, taken in connexion with the earthquakes and volcanic eruptions which occurred in June last in the Northern Island of New Zealand.

In order to show these relations between the two countries in question, I have prepared a map (Plate IX.) presenting the projection, of the antipods of the northern island and of part of the middle island of New Zealand, on the map of Spain. This projection is shaded, and the zone of maximum volcanic intensity in the northern island is represented by cross-hatching, being limited in one direc-

tion by the Tangaroro volcano, and on the other by White Island in the Bay of Plenty, also volcanic in its nature, and at present (September, 1886) in active eruption. The seat of the Andalucian earthquake, as also the points more markedly affected thereby, are within circles, the zone of greatest intensity being more deeply marked.

It will not be out of place to state summarily the main facts relative to the two earthquakes thus brought into relation.

That of Andalucia was described in *Nature*, vol. xxxi., p. 199 (January 1st, 1885); also in an article, "The Earthquake in Spain," p. 237, and in a note, p. 277, giving a *resumé* of Mr. Jos. Macpherson's remarks on the event, made before the Spanish Natural History Society, January 7th, 1885. From these it may be learned that a series of very violent earthquakes occurred in Andalucia during a period of some weeks, commencing at Christmas, 1884; that while the motion was felt so far north as Madrid, the district most severely visited lay in the provinces of Granada and Malaga, forming a parallelogram measuring about 70 miles from east to west, and about 35 miles from north to south. The eastern part of this district passed into the great range of the Sierra Nevada, of which the highest peaks rise to between 11,000 and 12,000 feet above the level of the sea. The area of maximum destruction lay in the western sierras, and covered the ground to the north and south of them. The greatest amount of damage was done at Alhama, which was almost entirely ruined. In Arenas del Rey 40 persons were killed; in Albuqueros 150; in Olivar 10; in Cijar 12; and numbers of like magnitude were reported from many towns and villages of the three provinces affected. The number of persons killed was estimated officially at more than 1000 persons. In the sketch-map published in *Nature*, vol. xxxi., p. 199, the following cities, towns, and villages, are indicated as having suffered shocks:—Madrid, Cuidad-real, Cordova, Jaen, Seville, Archidona, Granada, Antiquera, Cadiz, Malaga, Torrox, Almuñecar, Alham, Alfarnetejo, Periana, Jayena, Olivar, and Albuñuelas.

From the remarks made by Mr. Macpherson (vol. xxxi., p. 278), the following additional particulars are gathered:—

The earthquake presented marked coincidences with the geological structure of the country affected, and was divided by him into three successive phases—one of relatively slight importance,

which occurred in the early morning of December 22nd, and which was confined to the western portion of the country, its effects being felt only in Galicia and Portugal; another, of the highest importance, which occurred three days later, namely, at 9 p.m. on the 25th; while the third phase included the oscillations having taken place during a certain period subsequently in the districts most severely affected by the earthquake of the 25th. The earthquake extended over a very considerable surface, the district affected to an appreciable degree, including approximately, it would seem, the whole country lying between Cadiz and Cabo de Gata, and between Malaga and the Guadarrama range.

The shock was quite perceptible in Madrid, the direction of oscillation having been from north to south. The movement gained in intensity as it proceeded southwards, more especially after leaving the southern border of the central table-land, limited by the fault of the valley of the Guadalquiver. He called attention to the relation of the phenomena with the geological structure of the peninsula, and to the broad zone of great masses of granite, porphyry, diabase, and other kinds of rocks which cross the peninsula from Galicia to the valley of the Guadalquiver, and which, geologically speaking, divides the peninsula into two distinct parts.

"This huge belt (he says), which may be regarded as one of the most striking features of the peninsula of our day, cuts and divides the archaic formations, interrupting them in the Guadarrama central chain between the Sierra de Gata and the Estrella range in Portugal." This zone he considers as corresponding to a great line of fracture which crosses the peninsula from north-west to south-east, in the prolongation of which lies the region of earthquake shocks described by him. He concludes:—

"The two principal coincidences observable between the phenomena of the earthquake and the geological structure of the peninsula are—

"(1) That the disturbance of December 22nd was confined to the regions lying to the west of the zone described; and

"(2) That the most violent shocks of December 25th were experienced in the region intervening between the Sierra Nevada and the Sierra de Ronda, and precisely on the very belt which encloses the archaic mountain mass of the Sierras Tejea and

Almìjara, broken and torn by the secular 'disturbances of our globe.'

"There stood Alhama, now prostrate in the river bed; there Periana, a heap of ruins 3 m. high; there Albuñuelas, which exists no longer; there Zafarraya, Nerja, Torrox, and many other towns and villages, all testifying to the fragility of these faults, which, though dating back to the Silurian period, are still apparently not completely welded."

The examination of the map shows that the zone particularly referred to by Mr. Macpherson corresponds precisely to the axis of the antipodal projection of the North and Middle Islands of New Zealand on the map of Spain: that is to the antipodal projection of the zone of maximum volcanic intensity of the North Island. Moreover, the projection of the Coromandel promontory (New Zealand) not only coincides in its limits with the coast line of Malaga, but corresponds to the district represented as having been most affected. Alhama, the point of greatest destruction, lies exactly on the projection of the coast line of the promontory, as also Velez Malaga, while Malaga lies on the projection of the narrow headland which projects in a north-west direction from that promontory.

It may thus be asserted that the zone of maximum intensity of the Andalucian earthquake has for antipod the promontory forming the Thames and Coromandel districts of the North Island of New Zealand, the continuation of which, to the south and east, is the Tauranga, or volcanic district, the seat of the disturbance of June the 10th, 1886.

As regards this, not only has it been fully described by the local press of the country, but it has also formed the subject of two Government Reports—the one by Dr. Hector, Inspector of Mines, the other by Mr. Percy Smith, Assistant Surveyor-General, Auckland—Reports which have the signal merit of being both well done and quickly published.

The following extract from Mr. Percy Smith's Report (page 1) gives a description of the district affected:—

"If a line be drawn nearly south-west (true) from the top of Ruawahia, it will be found to indicate very closely a line of thermal action, extending from the base of that mountain to Orakako-

rako, along which, from time immemorial, have existed hot springs, geysers, and fumaroles, in immense numbers.

"Such a line will also pass along the wall-like western face of the Paeroa Mountain, at the base of which, in several places, hot springs and fumaroles have always existed.

"A little to the north of Paeroa is the Maounga-onga-onga Hill, on which no signs of recent action is apparent; but immediately to the east of it a country with innumerable hot springs, boiling mudholes, and lakelets, having on the east side the Kakaramea Mountain, where thermal action is very active, the greater part of the mountain having been steamed, and boiled, and coloured by subterranean vapours from top to bottom. In many places it is only necessary to make a hole in the surface to see the steam come forth. Further to the north-east the same line strikes through Rotomahana. It is thus obvious, that this line indicates an old line of activity and consequent weakness of the crust of the earth, and it is easy to show by varying its direction very slightly, or by treating it as a band of moderate width, that its production northwards would strike White Island, whilst in the opposite direction Tongariro and Ruapechu form the terminal points of activity southwards. "A reference to the four-mile map attached to the Report shows that the recent eruptions have followed very closely this line. Taking Wahanga as the most northerly point of activity, and Okaro Lake as the most southerly, it will be found to have extended a distance of nine and a-half miles. Along this line there may be said to be eight craters or points and groups of eruption (using the term crater in a somewhat extended sense, to include eruptions of a dissimilar character).

"*Earthquake Cracks.*—The heavy earthquake at 2 a.m. on the morning of the 10th June, and the constant and frequent shakes and tremors since, have caused cracks in several places. In the Waikorua Basin on the Rotorua-Galatea Road (a place where several cracks, one of about half a mile long and twenty yards wide, have been known from the earliest times), several new cracks have appeared, but of no great extent. We counted five across the path, but only one was as much as a foot in width. They invariably take the line of the older cracks running north-east and south-west. Mr. Morgan describes the cracks on the south side of Kakaramea to be very numerous, and in one place a spur from

that mountain is cracked and broken up to an extent to make crossing it very difficult. The north of Maounga-onga-onga is also much cracked."

In Dr. Hector's Report, page 2, is given a description of the "Great Fissure."

"This is the most remarkable and characteristic feature of the late eruption and the chief origin of the disastrous results which attended it. The fissure seems to commence in a narrow rift at the northern end from the great rent which has been formed in the south end of Tarrawera Mountain. This rent is a most wonderful feature. It is not a slip from the mountain side, but appears as if a portion of the mountain, measuring 2000 feet × 500 × 300 deep, had been blown out, leaving a ragged, rocky chasm, from which steam was being discharged in rapidly-succeeding puffs. Its general direction, as far as could be ascertained, is N. 50° E., which is the general line of direction that would connect all the more active geysers between Tangariro and White Island."

It may be concluded from these details that the most significant feature of the eruption and concomitant earthquakes was the great fissure extending from Tarawera Mountain to Okara Lake, a distance of about nine and a-half miles. The antipod of this fissure projects itself on the map of Spain in the immediate vicinity of the celebrated defile of Despeñaperros in the Sierra Morena, which connects the plateau of La Mancha with the great valley of Andalucia, and from the gorge of which a magnificent view of the valley is obtained. If the direction of the middle course of the Guadalquiver be produced, it cuts the antipod of the northern extremity of the fissure, that is, the point representing the antipod of Tarawera Mountain.

There is thus brought into relation three very interesting lines of earth fissuring—that traversing Spain from N.W. to S.E., that constituting the axis of the volcanic zone of the North Island, New Zealand, and the line of faulting which corresponds to the valley of the Guadalquiver.

The very remarkable mine of Almaden (which forms part of a great band of mineralized ground, extending in a line nearly east and west between the village of Chillon and a point to the east of Almadenejos), lies within the space covered by the projection of the

antipod of the North Island, and about 70 kilometres to the west of the projection of the antipod of the axis of maximum volcanic activity in the Northern Island.

It is further to be remarked that the earthquake mentioned by Mr. Macpherson as having occurred December 22nd in Galicia and part of Portugal affected a space representing the antipod of the northern part of the middle island of the New Zealand group, the outline of which corresponds in places with the coast line of Galicia. Moreover, as Mr. Macpherson states that the shock took place to the west of the N.W. and S.E. zone which crosses Spain as described by him, it is evident that its seat was close to the west coast of Galicia, which corresponds so remarkably with the antipod of the N.E. coast of the Middle Island.

An equally interesting feature of the comparison established by the map is, that the antipod of the western and more open portion of Cook's Straits corresponds to the mountain ranges of Sierra de Gata and Sierra de Gredos; the former, very wild, and but imperfectly explored as yet, attains a height of 1753 m. at the peak known as Peña de Francia; the latter, equally wild and grand in its scenery, attains a height of 2661 m. in the summit known as La plaza del Moro Almonzor. That is to say, a strait in New Zealand, said to be deep, corresponds as antipod to very lofty and wild mountain ranges in Spain, and necessarily the seats of vast geological disturbances. As if to point out more strongly these seeming antipodal relations, there have occurred within the last three months two further earthquakes in Spain, as regards the relations of which with the antipodal points of New Zealand projected on the map, the following details are of interest:—

In *Nature*, vol. xxxv., p. 59, occurs the note: "A shock of earthquake was felt in the district of Beira Alta (Portugal) on the 11th inst. (November, 1886). This district is described in Vivien de St. Martin's, "Dictionnaire de Geographie Universelle," as being watered by the affluents of the Deuro, the Vouga, and Mondego rivers; the principal towns are Vizeu and Guarda. This district lies, therefore, in that part of Portugal whereon falls the projection of the antipod of the Collingwood District, north-western extremity of the Middle New Zealand Island. Vizeu lies at about 32 kilometres, = 19½ miles, from the projection of the coast line, while Guarda corresponds very exactly as antipod to Cape Farewell.

The other earthquake recorded is that of 31st December, 1886, which occurred at Almeria, the antipod of which falls in the Bay of Plenty, at about 42·7 English miles north by east of White Island, the extremity of the line of the earthquake movements which shook that part of New Zealand the 10th of June last, and which island since is in a state of eruption.

XLII.—SUGGESTION RESPECTING THE EPIBLASTIC ORIGIN OF THE SEGMENTAL DUCT. By A. C. HADDON, M.A., M.R.I.A., Professor of Zoology in the Royal College of Science, Dublin. (Plate X.)

[Read, February 16, 1887.]

To Dr. V. Hensen is due the credit of first discovering the epiblastic origin of the segmental duct in the rabbit (*Lepus cuniculus*). He first recorded the fact in 1875 (5); but the observation appears to have been universally discredited, and even Balfour makes no mention of it in his "Treatise on Comparative Embryology." In 1884 Dr. G. F. Spee (11) found that the same occurred in the guinea-pig (*Cavia cobaya*), and in 1886 Professor W. Flemming (2) confirmed Hensen's account for the rabbit.

Towards the end of 1886, Dr. J. W. van Wijhe (13) announced that the segmental duct arose from the epiblast in the thornback ray (*Raja clavata*), and lastly, Dr. J. von Perényi (8) has very recently (January, 1887) extended this mode of origin to the frog (*Rana esculenta*) and to the lizard (*Lacerta viridis*).

The origin of the segmental duct from the epiblast being now known to occur in Elasmobranchs, Anura, Lacertilia, and Rodents, we are justified in assuming that this is a general and probably primitive mode of formation. With the above-mentioned exceptions, all embryologists who have recorded observations on the development of the duct agree in stating that it is at first placed immediately below the epiblast, and that it gradually sinks within the mesoblast, until it comes to lie close to the peritoneal epithelium; they also all agree in deriving the duct from the somatic mesoblast.

The duct arises in the Rodents as a linear proliferation of the epiblast in the region opposite to the intermediate cell-mass ("Grenzstrang" of Hensen). Flemming points out that the area is of variable length, not even being symmetrical. The separation of this solid cord of cells from the epiblast takes place from before backwards, and first occurs at a time when the mesoblastic somites

are still entirely continuous with the ventral (somatic and splanchnic) mesoblast. Hensen, Spee, and Flemming conjectured that the primitive kidney is itself developed from the epiblast in these Mammals, but of this they produce no direct evidence. It is more probable that the nephridia are of mesoblastic origin, as in other Vertebrates.

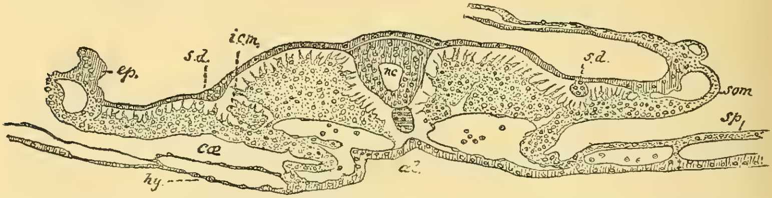

Fig. 1.—Transverse Section of Embryo Rabbit (4 mm. in length, stage of 16 somites). [After Flemming.]

The section is taken just in front of the posterior termination of the intestine. The right side of the figure is the left of the body. There is a small rupture in the left (right of figure) mesoblastic somite. *al.*, mesenteron (intestine); *cœ.*, cœlom (body-cavity); *ep.*, epiblast; *hy.*, hypoblast; *i.c.m.*, intermediate cell-mass; *n.c.*, neural canal; *s.d.*, segmental duct; *som.*, somatic mesoblast; *sp.*, splanchnic mesoblast.

Van Wijhe finds that in the ray the pronephros (Vornier) arises, at the commencement of Balfour's stage I., as a continuous evagination from the somatopleur on each side of the body throughout five somites. When the hinder end of this evagination reaches the skin, it fuses therewith, and the place of fusion is the rudiment of the duct of the pronephros (segmental duct). This grows posteriorly, gradually separating from the skin, so that its latest formed end is always fused with it. The mesonephros (Urnier) is developed shortly after the appearance of the pronephros.

In the frog Perényi finds that the duct develops as a canal-like separation from the inner (nervous) cell-layer of the epiblast, which later associates itself with the mesoderm cells of the intermediate cell-mass (Grenzstrang).

According to the usually-received account, formation of the segmental duct may take place in two ways—(1) either by the closing in of a continuous groove of the somatic peritoneal epithelium (Cyclostomi, anterior end only; Lepidosteus; Teleostei; Amphibia); or as a solid knob, or rod of cells derived from the

somatic mesoblast, which grows backwards between the epiblast and the mesoblast (Cyclostomi, posterior portion ; Elasmobranchii ; Amniota).

Balfour (1), appreciating the difficulties concerning the morphology of the duct, wrote thus :—"It is quite certain that the second of these processes is not a true record of the evolution of the duct; and though it is more possible that the process observable in Amphibia and the Teleostei may afford some indications of the manner in which the duct was established, this cannot be regarded as by any means certain."

One question always presents itself: this is—How did the segmental duct acquire its posterior connection with the cloaca? In the development of the duct this communication is effected later than its first appearance, but this, evidently, could not represent the ancestral condition. There are also several difficulties concerning the general homology of the nephridia themselves.

Balfour (1) discusses the problem in the following words:—"It is a peculiarity in the development of the segmental tubes, that they at first end blindly, though they subsequently grow till they meet the segmental duct, with which they unite directly, without the latter sending out any offshoot to meet them (Sedgwick maintains that the interior segmental tubes of the Chick form an exception to this general statement). It is difficult to believe that peritoneal infundibula ending blindly, and unprovided with some external orifice, can have had an excretory function, and we are therefore rather driven to suppose that the peritoneal infundibula, which became the segmental tubes, were either from the first provided each with an orifice opening to the exterior, or were united with the segmental duct. If they were from the first provided with external openings, we may suppose that they became secondarily attached to the duct of the pronephros (segmental duct), and then lost their external openings, no trace of these structures being left, even in the ontogeny of the system. It would appear to me more probable that the pronephros, with its duct opening into the cloaca, was the only excretory organ of the unsegmented ancestors of the Chordata, and that, on the elongation of the trunk and its subsequent segmentation, a series of metameric segmental tubes became evolved, opening into the segmental duct, each tube being in a sort of way serially homologous

with the primitive pronephros. With the segmentation of the trunk the latter structure itself may have acquired the more or less definite metameric arrangement of its parts."

"Another possible view is, that the segmental tubes may be modified derivatives of posterior lateral branches of the pronephros, which may at first have extended for the whole length of the body cavity. If there is any truth in this hypothesis, it is necessary to suppose that, when the unsegmented ancestor of the Chordata became segmented, the posterior branches of the primitive excretory organ became segmentally arranged, and that, in accordance with the change thus gradually introduced in them, the time of their development became deferred, so as to accord to a certain extent with the time of formation of the segments to which they belonged. The change in the mode of development which would be thereby introduced is certainly not greater than that which has taken place in the case of segmental tubes, which, originally developed on the Elasmobranch type, have come to develop as they do in the posterior part of the mesonephros of Salamandra, Birds, &c."

In his "Comparison of the Excretory Organs of the Chordata and Invertebrata" (*l. c.* p. 607), Balfour states:—"The excretory organs of the Platyelminths are in many respects similar to the provisional excretory organ of the trochosphere of Polygordius and the Gephyrea on the one hand, and to the Vertebrate pronephros on the other; and the Platyelminth excretory organ, *with an anterior opening*, might be regarded as having given origin to the trochosphere organ, while that *with a posterior opening* may have done so for the Vertebrate pronephros (this suggestion has, I believe, been made by Fürbinger).

"Hatschek has compared the provisional trochosphere excretory organ of Polygordius to the Vertebrate pronephros, and the posterior Chætopod segmental tubes to the mesonephric tubes, the latter homology having been already suggested, independently, by both Semper and myself [Balfour]. With reference to the comparison of the pronephros with the provisional excretory organ of Polygordius, there are two serious difficulties:—

"(1) The pronephric (segmental) duct opens directly into the cloaca, while the duct of the provisional trochosphere excretory organ opens anteriorly, and directly to the exterior.

"(2) The pronephros is situated *within* the segmented region of the trunk, and has a more or less distinct metameric arrangement of its parts; while the provisional trochosphere organ is placed *in front* of the segmented region of the trunk, and is in no way segmented.

"The comparison of the mesonephric tubules with the segmented excretory organs of the Chætopoda, though not impossible, cannot be satisfactorily admitted till some light has been thrown upon the loss of the supposed external openings of the tubes, and the origin of their secondary connexion with the segmental duct."

The difficulties concerning the phylogeny of the segmental duct led Sedgwick (9) to the hypothesis that the duct may be compared with "the circular canal of Medusæ, which might easily be conceived transformed into the Vertebrate segmental duct, the excretory organs themselves being developed from the outer part of the radial canals." At a more primitive stage in the evolution of Chordata he suggests that "the primitive alimentary canal acquired a well-arranged system of ducts, by which the peripheral excretory matters were carried to the part of the alimentary canal near the hind end of the primitive mouth (future anus); that, in consequence, the excretory pores [such as occur in the circular canal of Medusæ] were not wanted, and were either never developed, or, if developed, lost."

Sedgwick summarises his conclusions thus:—"With regard to the endodermal organs, the pouches [archenteric diverticula] have become differentiated into two kinds—

"(1) Anteriorly a certain number retain their communication with the exterior and with the gut.

"(2) The majority, however, lose their connexion with the gut and with the exterior, but remain connected by the peripheral canal, which behind retains (by means of a pouch?) its communication with the gut.

"(3) A posterior pouch loses its connexion with the gut and with the longitudinal canal, and gives rise to an *abdominal pore.*

"The first group of pouches become the *gill-slits*, the second become the *cœlom*, while part of each of them become differentiated into *nephridia*, which opens into the longitudinal canal (pronephric or segmental duct). The last pair of pouches gives rise to a part

of the cœlom, and retains its connexion with the exterior as an abdominal pore."

Lang (7) appears to have been the first to compare the pores which put the gastro-vascular system of Cœlenterates into direct communication with the exterior with structures found outside that group. He says:—"In certain Polyclades [Turbellaria] ramifications of the intestine open to the exterior by excretory pores, either on the dorsal surface (*Planaria aurantiaca* d. Ch.), or on the lateral edge (as in a very interesting new genus of the family of Proceridæ), thus forming a complete analogy with the excretory pores which are found at the edge of the bell in certain Medusæ.

"The aquiferous system characteristic of other Platyelminths does not occur in the Polyclades. The secretory organs of these animals are formed after the type of those of the Cœlenterata. excretion in the two groups is performed by means of diverticula from the intestine which open to the exterior."

Van Wijhe (13) believes that "the primitive Craniotes possessed no pronephric duct, the pronephros opening to the exterior by a pore laterally from the gland. This orifice migrated later posteriorly, and its outer border developed into the duct, and coming into contact with the cloaca, opened into it." He further goes on to say, that the epiblastic origin of the segmental duct will not be welcome to those who hold that the Chordata were descended from Annelids; but, for his part, he cannot admit the relationship between these types.

Without at all committing myself to a belief in the ancestry of the Chordata from Chætopod Worms, I would offer the following considerations as tending to show that the Vertebrate excretory system is readily comparable with that of Annelids, now that the epiblastic origin of the segmental duct has been established.

It is perfectly well known that the nephridia of all Invertebrates open directly to the exterior, and in the segmented Worms there are typically a pair of nephridia for each somite. The diagrams (Plate X., figs. 1 and 2) schematically represent this arrangement.

It is generally admitted that the early (not necessarily the *primitive*) Chordata were segmented, and it is not unreasonable to suppose that the nephridia were segmentally disposed, as there is

usually a marked segmental arrangement of the nephric tubules in ontology. The peripheral orifices of the nephridia must either have opened directly to the exterior, or from the first debouched into a longitudinal canal. Various theories have been framed to explain the latter arrangement; but the former condition is undoubtedly more easily conceived, one difficulty in this supposition being—What has become of the primitive external openings?

Accepting the proposition that the primitive Chordata nephridia opened directly to the exterior, we have only to assume that the lateral area along which they opened was grooved, and that this groove extended posteriorly as far as the anus (Plate X., figs. 3–5).

From the analogy of the neural groove, there is no great difficulty in further supposing that the nephric groove was converted into a canal, which, becoming separated from the overlying epiblast, might sink into the deeper-lying parts of the body.

If a suggestion may be hazarded concerning the advantage of converting the nephric groove into the nephric duct, it may be pointed out that the lateral openings of the nephridia would not be far removed from the branchial clefts, and the need of pure water for respiratory purposes is emphasised by the now acknowledged fact, that each cleft was provided with its own sense-organ (now metamorphosed into the "thymus gland"). The development of the duct from before backwards supports this view.

From recent researches on the Lamprey [Shipley, 10], Newt [Alice Johnson, 6], Alytes [Gasser, 4], and Frog [Spencer, 12], it has been proved that in these forms the blastopore never closes up, but persists as the anus (*i.e.* the opening of the mesenteron into the cloaca).

We are justified in assuming the persistence of the blastopore as the anus in early Chordata: thus, if the nephric groove were continued round to the anus, it would practically open into the extreme hinder end of the mesenteron, in other words, into the urodæum [Gadow, 3].

Probably about the same time that the nephric groove was being converted into the nephric canal (segmental duct) the proctodæum was being invaginated. The latter would push before it the posterior orifice of the nephric canal, as is represented in Plate X., fig. 6.

The nephridia themselves appear to be of mesoblastic origin. It is possible that the archinephros extended throughout the greater length of the body, as in Chætopod Worms, but that in time an anterior section (pronephros) came to be developed earlier than the posterior portion (mesonephros).

The precociousness in the development of the segmental duct in ontogeny is not necessarily a difficulty, as it can be paralleled by many other organs.

On the hypothesis just sketched out, the nephridia always open by their original epiblastic pores—primitively, directly to the exterior; secondarily, into a canal separated from the epiblast: also the archinephros could be equally effectively functional throughout the whole period of its modification.

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3. Gadow, H., . . "Remarks on the Cloaca and on the Copulatory Organs of the Amniota," *Proc. Roy. Soc.*, 1886.

4. Gasser, E., . . "Zur Entwicklung von Alytes obstetricans." *Sitzungsber. d. Marburger Naturgesell*, 1882.

5. Hensen, V., . . "Beobachtungen über die Befruchtung und Entwickelung des Meerschweinchens und Kaninchens," *Arch. f. Anat. u. Phys.*, 1875.

6. Johnson, A., . . "On the Fate of the Blastopore and the Presence of a Primitive Streak in the Newt (Triton cristatus)," *Quart. Journ. of Micr. Sci.*, xxiv., 1884.

7. LANG, A., . . "Sur les Relations des Platyelmes avec les Celentérées d'un côté et les Hirudinées de l'autre," *Arch. de Biologie*, ii., 1881.

8. PERENYI, J. VON, . "Die ectoblastische Anlage des Urogenitalsystems bei Rana esculenta und Lacerta viridis," *Zool. Anz.*, x., 1887.

9. SEDGWICK, A., . "On the Origin of Metameric Segmentation and some other Morphological Questions," *Quart. Journ. of Micr. Sci.*, xxiv., 1884.

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13. WIJHE, J. W. VAN, "Die Betheiligung des Ektoderms an der Entwicklung des Vornierenganges," *Zool. Anz.*, ix., 1886.

[EXPLANATION OF PLATE X.

EXPLANATION OF PLATE X.

DIAGRAMS ILLUSTRATING THE PROBABLE EVOLUTION OF THE SEGMENTAL (ARCHINEPHRIC) DUCT.

a., primitive anus, or urodæum (blastopore); *al.*, alimentary canal; *ao.*, dorsal aorta; *cœ.*, cœlom; *e.o.*, external orifice of nephridium; *gl.*, glomerulus of archinephros; *gr.*, nephric groove; *i.o.*, internal (cœlomic) ciliated orifice of nephridium; *pr.*, proctodæum (epiblastic cloaca); *s.d.*, segmental (archinephric) duct.

Fig. 1.—Horizontal view of the arrangement of the nephridia in Segmented Worms.

,, 2.—Transverse section through the body of an Earthworm (*Lumbricus*).

,, 3.—Transverse section through the trunk of a hypothetical primitive representative of the Chordata.

,, 4.—End view of the same, to show the anus lying within the nephric groove.

,, 5.—Horizontal view of probable disposition of the nephridia of the same.

,, 6.—Horizontal view of ideal archinephros of the lower Vertebrates.

XLIII.—NOTE ON THE ARRANGEMENT OF THE MESENTERIES IN THE PARASITIC LARVA OF *HALCAMPA CHRYSANTHELLUM* (Peach). By A. C. HADDON, M.A., M.R.I.A., Professor of Zoology in the Royal College of Science, Dublin. (Plate XI.)

[Read, February 16, 1887.]

In 1859 L. Agassiz recorded from the east coast of North America an Actinia parasitic on Medusæ, which he named *Bicidium parasitica.* This has since been found by Verrill in 1862, and by A. Agassiz in 1865. Still more recently (1884), Mark [1] has given a preliminary account of a larval Edwardsia, which is parasitic within the gastro-vascular canals of the Ctenophore *Mnemiopsis leidyi.*

On this side of the Atlantic, T. Strethill Wright, in 1859, gave an account of a small Actinia, also parasitic, on Hydromedusæ, from the Firth of Forth, which he named *Halcampa Fultoni;* and, in the following year, F. Müller described a similar form, which he named *Philomedusa vogtii,* from the Santa Catherina, on the Italian Riviera. E. Graeffe described, in 1883, a parasitic Halcampa from the Adriatic, which, "as the development of *Halcampa chrysanthellum* is not known, this form must, provisionally, be separated from *H. chrysanthellum* as *H. medusophila.*"

The author exhibited, and made remarks upon, two specimens of a parasitic Halcampa at a meeting of the Royal Irish Academy, on June 22, 1885, and a record was published in the following year. In this communication it is stated that Prof. A. Macalister of Cambridge (late of Dublin) had informed the author, by letter, that he had met with this Halcampa, and perhaps another form, but neither of them in Dublin Bay. Specimens were also obtained in Dublin Bay in June, 1886, and on June 6, in the same year, off

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[1] "Selections from Embryological Monographs," compiled by A. Agassiz, W. Faxon, and E. L. Mark, Bull. Mus. Comp. Zool., Harvard Coll. (Camb., U. S. A.), p. 43, pl. xii.

Ballycotton, Co. Cork. On the same day *Halcampa chrysanthellum* was dredged from fifty-two fathoms.

Bibliography of Larval Actiniæ Parasitic on Medusæ.

North European Seas.

Peachia fultoni, . .	T. Strethill Wright, 1859, *Proc. Roy. Soc. Edinb.*, ii., p. 91, 1860 ; *New Edinb. Phil. Journ.*, xii., p. 156.
Halcampa, ,, . .	Reprinted in *Ann. Mag. Nat. Hist.* (3), viii., 1861, p. 132.
,, ,, . .	G. Leslie and W. A. Herdman, 1881, *Invert. Fauna of Firth of Forth*, p. 63 (merely repeats Wright's record).
Philomedusa ,, . .	A. Andres, 1883, *Le Attinie, Atti. Acc. Rom.* (3 A). xiv. [*Fauna, u. Fl. d. Golfes v. Neapel* (1884), p. 114.]
Halcampa chrysanthellum,	A. C. Haddon, 1886, *Proc. Roy. Dublin Soc.* (N. S.), v., p. 11 ; *Proc. Roy. Irish Acad.* (2), iv., Sci., p. 527. (Noted in *Zoologist*, 1886, p. 7).

There can be little doubt concerning the justice of considering the above to be the larval form of *Halcampa chrysanthellum ;* the form, colour, structure, and histology support this conclusion.

In the only three localities where the parasitic larva has been hitherto found the adult *Halcampa chrysanthellum* has also been obtained, viz. Firth of Forth (Leslie and Herdman, *loc. cit.*, p. 62, on the authority of F. E. Schulze, "Zoologische Ergebnisse der Nordseefahrt," III. Coelenterata, p. 140 : Berlin, 1874), Dublin Bay, and Cork (A. C. H.).

In a former paper [*Proc. Roy. Dubl. Soc.* (N.S.), v., 1886, p. 1] I have endeavoured to show that the forms known as *Edwardsia duodecimcirrata*, Sars (from Norway and E. Denmark), *Zanthiopus bilateralis*, Kef., and *X. vittatus*, Kef. (from N. France), are one and the same with this species. If this be so, the parasitic larva must have an equally North European range.

Mediterranean.

Philomedusa vogtii, . .	Fritz Müller, 1860, *Wiegmann's Archiv f. Naturg.*, xxvi., p. 57 [reprinted in *Ann. Mag. Nat. Hist.* (3), vi., 1860, p. 432.]
,, ,, . .	A. Andres, 1883, *Le Attinie*, *Attc Acc. Rom.* (3 A), xiv. [*Fauna u. Fl. d. Golfes v. Neapel* (1884), p. 112].
Halcampa medusophila, .	E. Graeffe. 1883, *Boll. d. Soc. Adriatica di Sci. Nat. Trieste*, vii.

As *Halcampella endromitata* (Andres), is the only Mediterranean example of the Halcampidæ, the above-mentioned forms are probably the parasitic larva of that species.

Coast of New England—North-East America.

Bicidium parasiticum, .	A. Agassiz, 1859, *Proc. Boston Soc. Nat. Hist.*, vii. (1861), p. 24.
,, ,, .	A. E. Verrill, 1862, *Mem. Boston Soc. Nat. Hist.*, i. (1866), p. 31, pl. i., figs. 14, 15.
,, ,, .	E. C. and A. Agassiz, 1865, *Seaside Studies in Natural History*, *Boston*, p. 15, fig. 14.
Peachia parasitica, . .	A. E. Verrill, 1866, *Proc. Boston Soc. Nat. Hist.*, x., p, 338.
,, ,, . .	A. E. Verrill, 1873, *Report U. S. Fish Com.*, i., 1871–2, p. 739.
Philomedusa ,, . .	A. Andres, 1883, *Le Attinie*, *Atti. R. Acc. Lincei*, *Rome* (3 A), xiv. (*Fauna u. Fl. d. Golfes v. Neapel*, 1884, p. 112, fig. 9.

From Verrill's accounts (1862 and 1866) there can be no doubt that the above parasitic Anemone is really a Peachia; it must, therefore, be known, for the present, as *P. parasitica*; but in the latter paper Verrill states that it is very much like *Siphonactinia* (*Peachia*) *Bœckii* (Dan. & Kor. 1856) in form and colour. The

colour is purplish-brown, or red, and the length 32 mm. – to 46 mm. With the exception of two specimens of very large size found buried in the gravel, at low water-mark, at Eastport, Maine (Verrill, 1873), this form is only known as parasitic in the lip-folds of *Cyanea arctica*, from Cape Cod to the Bay of Fundy.

Southern Ocean.

Actinia clavus, . .	Quoy et Gaimard, 1833, *Voyage de l'Astrolabe*, p. 150, pl. x., figs. 6, 11.
Iluanthos ,, . .	Milne Edwards, 1857, *Hist. Nat. des Coralliaires*, i., p. 284.
Philomedusa clavus, . .	Andres, 1883, *Le Attinie, Atti. Acc. Rom.* (3 A) xiv. [*Fauna u. Fl. d. Golfes v. Neapel* (1884), p. 114.]
Halcampa ,, . .	R. Hertwig, 1882, *Actiniaria*, "*Challenger*" *Reports*, p. 92.

Quoy and Gaimard found several specimens of this Halcampa entangled (*engagés*) in the tentacles of a medusa. It was 7–8 lines long in its greatest extension, and only three when contracted; translucid white in colour; 12 short tentacles. They obtained it in Bass' Straits, Australia, lat. 38° S.

R. Hertwig identifies an Halcampa dredged by the *Challenger* at Kerguelen (25–120 fathoms) as this species.

It is interesting to observe that certain (at least) of the members of the three families, Edwardsidæ, Halcampidæ, and Siphonactinidæ, pass through a stage during which they are parasitic on Medusæ or Ctenophores. There is now a good deal of evidence in favour of the view, that the Edwardsidæ and Halcampidæ are more closely related than was formerly thought to be the case; and, so far as my investigations on Peachia have gone, I am led to believe that the Siphonactinidæ are closely related to the latter. Be this as it may, the genus Philomedusa must now be discarded.

As before mentioned, in 1885 I found one or two specimens of the larval Halcampa in Dublin Bay, and again in 1886, in July of that year, I also found a specimen off the coast of Cork. They

were usually attached to the stomach on the sub-umbrella (Pl. XI., figs. 1, 2) of different species of Leptomedusæ. Occasionally they adhered to the margin of the disc. With a little care they can be kept alive some time, and will feed on small pieces of meat when medusæ are not to be had.

When first obtained some specimens measured a little under 3 mm. in length, and one grew to about 5 mm. in length.

The body was sub-conical in form, the column not being distinctly divided into the three regions (capitulum, scapus, and physa) so characteristic of the adult. The middle portion was especially corrugated, and indented at the insertion of the mesenteries. The body could be slowly lengthened or contracted; it was uniformly clothed with small cilia. There were only eight short tentacles. At first they were very short, but afterwards they grew relatively longer.

The Medusa appears to be but little incommoded by the parasite; but it probably succumbs in time to its guests. In its ordinary condition the Anemone sinks in the water when taken from the Medusa; but it can extrude its mesenteries through its mouth for a considerable distance (Pl. XI, fig. 5). These enable it to float at the surface of the water, and, at the same time, to attach itself to passing Medusæ. This is probably the manner by which it secures a continual supply of food.

They had a uniform yellowish flesh-colour, with eight rudimentary tentacles. The tentacles grew longer, and were tinged with brown and yellowish white. The disc also became variegated with brown, and the body translucent, revealing the yellow œsophagus. At the last observed stage the body was almost colourless—the œsophagus yellow, the capitulum possessed a pair of cream-coloured spots below each tentacle, and the insertion of the mesenteries were of the same colour—the eight tentacles had on their oral surface two transverse bars of white at the base, and a single bar half-way along their length. Above this was a large brown spot, and a pair below it; and above the basal lines, between the two brown spots, is a small white one. The disc was prominent, with white radial lines, the areas being brown, finally speckled with white, each having prominent white spots at the mouth.

Although there were eight tentacles there were twelve mesenteries. The tentacles were arranged in two groups of three, and a

single tentacle between each group. A deep siphonoglyphe, was present, thus causing the mouth to be T shaped. The siphonoglyphe, being in the axial line, indicates the disposition of the tentacles. On reference to Pl. XI., fig. 4, it will be seen that the intermesenterial chamber on each side of the axial or directive chamber is produced into a tentacle. Of the three remaining lateral chambers, only the centre possesses a tentacle.

All the previous accounts of the parasitic larva of Halcampa agree in the fact of twelve tentacles being present. This can only be accounted for by supposing that the larvæ were more developed than mine. This was certainly the case in Strethill Wright's specimens, and in my oldest examples I found indications of the sprouting of some of the missing tentacles. It is, of course, possible that the Mediterranean form acquires its twelve tentacles very early.

Meyer and Möbius (Arch. f. Naturg., 1863, p. 70) mention that in their adult examples of "*Edwardsia duodecimcirrata*," Sars. [*Halcampa chrysanthellum*], the number of tentacles varied from eight to twelve, but never more than the latter number.

By making a series of transverse sections I was enabled to trace out the arrangement of the mesenteries in a more satisfactory manner than could be effected by an examination of the living animal.

In the œsophageal region, the twelve mesenteries appear to have equal importance. The siphonoglyphe causes what may be termed the ventral directive mesenteries to be much bent. At the lower extremity of the œsophagus four of the mesenteries fall short of joining the œsophagus. The siphonoglyphe extends for a short distance beyond the œsophagus proper (Pl. XI., fig. 8).

In the gastric region of the body there are eight large mesenteries, which alone bear the swollen digestive borders. It will be noticed that it is those intra-mesenterial chambers, bounded by a strong and a weak mesentery, which are not prolonged into tentacles. The dorsal directive mesenteries also appeared somewhat smaller than the remaining six. The same general arrangement occurred at the posterior end of the body, except, of course, that the mesenteries have no thickened edges.

It is probable that at a slightly earlier stage only the eight strong mesenteries are present, as an increase in the number of tentacles with the growth of the animal is characteristic of most

sea-anemones, and in our species the adult has twelve rudimentary mesenteries in addition to the twelve primaries [cf. *Proc. Roy. Dub. Soc.* (N.S.) v., 1886, p. 12, fig. 4]. The same occurs in *H. arenacea*, Haddon[1]; but according to R. Hertwig, there are only the twelve primaries in *H. clavus*, Quoy et Gaimard.

The brothers Hertwig[1] first insisted upon the systematic importance of the disposition of the muscular bands on the mesenteries. A comparison of the diagrams on Pl. XI. will demonstrate the fact that the eight strong mesenteries of the larval Halcampa perfectly corresponds with the eight mesenteries of Edwardsia. The Hertwigs have further shown that the normal Hexactina pass through a stage in which there are eight strong and four weak mesenteries (Pl. XI., figs. 10, 11); but it will be seen that these mesenteries do not correspond with those of the larval Halcampa and adult Edwardsia on the one hand, or with those of the Octactiniæ on the other.

The inequality in the development of the septa of the adult Halcampa was first pointed out by R. Hertwig[2] (Actiniaria, "*Challenger*" *Reports*, Zoology, vi., 1882, p. 95). He found that four were somewhat smaller than the eight others. I have quoted (*loc. cit.* pp. 7, 8, footnote) an observation of Dixon's confirming this, and Strethill Wright found the same in his larval form. He says:—"Eight septa were continued downwards to the lower extremity of the body, and had their free edges bordered by a convoluted ciliated band, furnished with cnidæ, or thread cells; the intersepta (*i.e.* the four smaller mesenteries) bore no convoluted bands."

On a future occasion I propose to give a detailed account of the anatomy of *Halcampa chrysanthellum;* for the present I would merely state that I find that, in the adult, the generative organs only occur on six mesenteries. These correspond with the eight strong mesenteries mentioned above, less the dorsal pair. The axial, or directive mesenteries, which support the siphonoglyphe, are here considered as the ventral, and the opposite pair as the dorsal.

The Hertwigs also pointed out that the Actinidæ (larval forms)

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[1] First Report "On the Marine Fauna of the South-west of Ireland—Actinozoa," *Proc. R. Irish Acad.* (2) iv. (Sci.), 1886, p. 616.

[2] Die Actinien (Studien zur Blättertheorie), O. and R. Hertwig, Jena, 1879.

Edwardsiæ, and Alcyonaria exhibit three different ways in which the eight mesenteries may be disposed. They regarded the mesenteries as symmetrical—*i.e.* four dorsal and four ventral in the Actinidæ, as six dorsal and two ventral in the Edwardsiæ, while in the Alcyonaria all the eight mesenteries are dorsal.

Although my observations are incomplete, I have thought it desirable to place them on record, as it may be some time before I am able to discuss the question at greater length. For the present, we may assert that, although the adult Halcampa closely resembles the ordinary Actiniæ in the ratio of its tentacles, and the disposition of its mesenteries, the larval form is undoubtedly more nearly related to the Edwardsiæ.

EXPLANATION OF PLATE XI.

(*Figs.* 6-14 *are purely diagrammatic.*)

Fig. 1.—*Thaumantias globosa*, Forbes (*Phialidium variable*, Hæckel), with parasitic Halcampa; nat. size.

„ 2.—The same; magnified 4 diameters.

„ 3.—Parasitic larva of *Halcampa chrysanthellum*, older than that of fig. 1; magnified 5 diameters.

„ 4.—Oral disc of a still older larva, with eight tentacles, but twelve mesenteries, and showing the siphonoglyphe.

„ 5.—Oral aspect of larva with extended mesenteries; about 5 diameters.

„ 6.—Transverse section of larval Halcampa through the middle of the œsophagus (stomodæum).

„ 7.—Transverse section of larval Halcampa through the lower portion of the œsophagus (stomodæum).

„ 8.—Transverse section of larval Halcampa immediately below œsophagus (stomodæum).

Fig. 9.—Transverse section of larval Halcampa in the gastric region.

,, 10.—Transverse section of young larva of *Aptasia diaphana* (after R. and O. Hertwig).

,, 11.—Transverse section of slightly older larva of *Aptasia diaphana* (after R. and O. Hertwig).

,, 12.—Transverse section of adult *Edwardsia tuberculata* through the œsophagus (after R. and O. Hertwig).

,, 13.—Transverse section of adult *Alcyonium digitatum* through the œsophagus.

,, 14.—Transverse section of adult *Funiculina quadrangularis* through the œsophagus (after A. Milnes Marshall).

XLIV.—NOTE ON A GRAPHICAL METHOD OF SOLVING CERTAIN OPTICAL PROBLEMS. By HOWARD GRUBB, F.R.S.

[Read February 16, 1887.]

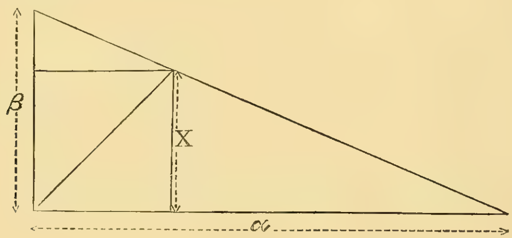
In the calculation of curves of optical lenses it is frequently required to add and subtract reciprocals; and formulæ of the form

$$\frac{1}{a} \pm \frac{1}{\beta} = \frac{1}{x}$$

are of constant recurrence.

In the study, where a logarithm book is available, the arithmetic of this is generally very simple; but in the workshop or laboratory a graphical method of solving the problem is often more convenient, particularly in the hands of workmen who have not had a mathematical training.

In the working out of some optical diagrams on logarithmic paper I accidently arrived at the following graphical solution, which I have found very useful, and on the principle of which I am constructing a calculating machine suitable for solving these particular problems:—



Draw a horizontal line = the a of above formula, and erect at one extremity a vertical = β. Join the extremities of these two lines. Bisect the right angle, and produce the bisecting line till it reaches the line joining the extremities of the lines a and β. From the

point of intersection drop a perpendicular on the line a, and the length of this perpendicular on the same scale will be equal to x in above formula, or $= \frac{a\beta}{a + \beta}$.

According to this principle, a machine can be constructed in which the various quantities can be read off by scales, without any calculation whatever.

I hope shortly to be able to exhibit such a machine to the Royal Dublin Society.

XLV.—AN EXPERIMENT ON THE SURFACE TENSION OF LIQUIDS. By A. R. WALSH. (Communicated by F. T. Trouton, B. E.)

[Read, February 16, 1887.]

The fact that an oily needle will float on the surface of water has been known for a long time, and is often referred to as an experiment illustrating the tension of the surface between water and air.

If a medium-sized needle (No. 6) is placed floating on water, and olive oil is gently poured on the surface of the water, until the needle is covered by the oil, the needle sinks to the bottom of the water.

But if the same experiment be made, using this time petroleum instead of olive oil, the needle will remain floating on the surface of the water.

The depression formed by the needle and oil resembles a boat, the sides of which are formed by the depressed surface of the water, while the contents consist of the oil and the needle.

If the needle used in the two experiments be the same, the amount of oil in the boat depends upon the specific gravity of the oil; while the amount of oil the boat will bear without the sides giving way depends upon the strength of the sides, that is to say, on the superficial tension.

Let

V and δ be the volume and density of the water displaced;

V' and δ' be the volume and density of the oil in the boat;

V'' and δ'' be the volume and density of the needle;

then

$$V\delta = V'\delta' + V''\delta''. \tag{1}$$

$$V = V' + V''. \tag{2}$$

$$V' = V''\frac{\delta'' - \delta}{\delta - \delta'}. \tag{3}$$

Since δ' is always nearly equal to δ, and small compared with δ'',

the value of the fraction in (3) depends upon the value of δ'. The volume of water displaced, therefore, varies as V'' and as δ'.

The following Table, taken from the memoir of M. Quincke, gives in grammes weight per lineal metre, the tension of the surface at 20° C., separating water from air, olive oil, and petroleum :—

Superficial Tension in Grammes Weight per Lineal Metre.

Between water and air, . . .	8·253
Between water and olive oil, . .	2·096
Between water and petroleum, . .	2·834

Specific Gravities.

Olive oil, ...	·915
Petroleum, ...	·840.

When olive oil is poured on the surface of water upon which a needle is floating, the high specific gravity of the oil, and the weakness of the surface separating it from water, combine together to sink the needle.

In order that a needle should be able to float between olive oil and water, it would be necessary for the weight of water displaced to be twice as great as the weight of water displaced when the same needle floats between petroleum and water.

With a certain needle, the volume of the water displaced was found to be thirty-five times the volume of the needle.

In order that the same needle might float between olive oil and water, the volume of water displaced would require to be seventy times the volume of the needle.

It is possible for a very small needle to float on water which is covered by olive oil; for by halving the volume of the needle, the volume of the water displaced is at the same time halved.

XLVI.—THE BLACK MARBLE OF KILKENNY. By W. N. HARTLEY, F. R. S., Professor of Chemistry, Royal College of Science, Dublin.

[Read, February 15, 1887.]

This well-known marble is highly esteemed on account of its jet-black appearance and the high polish which it is capable of receiving. Last April I visited the quarries from which it is procured, and observed certain properties belonging to it of which I can find no description. It is mentioned in Sir Robert Kane's work on "The Industrial Resources of Ireland" that the exposed and weathered surfaces of the rock possess a yellow ochreous colour. This might be due to the colour of the freshly-hewn stone being caused by the presence either of ferrous sulphide or of ferrous carbonate, which, in presence of carbonic acid and air, became dissolved and oxidised. The disappearance of the black colour from the surface was remarkable. On striking a block of the marble with a hammer or large stone it emitted a ringing metallic sound. When portions were broken off, the fractured surface smelt of sulphuretted hydrogen. Under similar circumstances the German "Stinkstein" is said to smell of bituminous matter. The constituents of the mineral were determined by Mr. J. E. Purvis, a student in the Royal College of Science; the results of his examination are here given:—

Chemical Analysis.

When the mineral was finely powdered and thoroughly mixed its colour was a little lighter, but still what may be described as black. Carbon dioxide was determined by Fresenius and Will's method: the escaping gas smelt of sulphuretted hydrogen.

Estimation of Sulphuretted Hydrogen.—It was found by Mr. Fred Ibbotson, who made a qualitative examination of the mineral, that sulphuretted hydrogen was liberated by acetic acid, also that precipitated ferrous sulphide is decomposed by acetic acid; therefore nothing could be learnt by dissolving the

mineral in acetic acid. The gases evolved by hydrochloric acid acting upon ten grams of the substance were passed through two U tubes containing acidulated solution of copper sulphate: a brown precipitate formed only in the first limb of the first tube; this was collected on a filter, washed, dried, and weighed. It was considered that as the quantity collected was very small, and water was contained in the mineral, that the sulphuretted hydrogen was in solution in fluid enclosures too small to be visible, and that possibly it was present as calcium sulphydrate. A large quantity of the substance was crushed under distilled water, and on testing the liquid with lead paper a black stain of lead sulphide was obtained. The aqueous solution was filtered; the filtrate was evaporated to dryness, and a light-brown residue was left. Examined with the spectroscope, the residue was found to contain a compound of calcium only. Another portion, crushed under water, filtered, and treated with ammonium chloride, ammonia, and ammonium oxalate, yielded a white precipitate, small in amount, and consisting of calcium oxalate. A portion of the residue left after evaporation of the aqueous solution was oxidised with nitric acid, and tested with barium chloride, by which treatment a precipitate of barium sulphate was obtained.

Copper.—After solution of the mineral in hydrochloric acid and evaporation to dryness, to separate silica in the usual way, a current of sulphuretted hydrogen, passed for some time through the hot solution, separated a small quantity of copper sulphide. This was filtered, washed, dried, transferred to a crucible, heated with a few drops of strong nitric acid, and the iron precipitated by ammonium chloride and ammonia, dried, and weighed.

Calcium and Magnesium.—These were precipitated in the usual manner.

Organic Matter.—The black residue, insoluble in hydrochloric acid, was collected on a weighed filter, washed well with hot water, and dried at a temperature of 100° C. A weighed portion of this was placed in a platinum boat, and burnt in a current of oxygen; a very slight residue, apparently ferric oxide, remained. The carbon dioxide and water were collected in the usual manner and weighed. The organic matter was almost entirely carbon: no hydrogen could be calculated from the amount of water collected, hence the carbonaceous matter was apparently of the nature of anthracite.

To ascertain whether bituminous substances were present, the crushed mineral was treated with pure alcohol, which was first proved to leave no residue on evaporation. The liquid was filtered, the filtrate evaporated to dryness, and a light-brown residue obtained. A portion of this was moistened with a drop of hydrochloric acid, and an addition of ammonium chloride, ammonia, and ammonium oxalate yielded a precipitate of calcium oxalate. Another portion, treated with nitric acid and subsequently with barium chloride gave a precipitate of barium sulphate. A similar result was obtained by treatment with pure ether. In neither instance was any organic matter dissolved. These extracts by alcohol and ether prove the existence of calcium sulphydrate in the mineral; hence the odour when the mineral is broken. The analytical numbers are the following:—

	(1.) Per Cent.	(2.) Per Cent.
CO_2,	[1] 40·409	40·409
CaO,	55·360	54·920
FeO,	0·342	0·290
CuO,	0·054	0·064
MgO,	0·243	0·249
SiO_2,	1·436	1·308
Water,	0·596	
Carbon,	1·482	2·091
Sulphur,	0·013	
	99·935	99·331

[1] Mean of three determinations.

XLVII.—MARBLES AND LIMESTONES. By G. H. KINAHAN, M. R. I. A.

[Read, February 16, 1887.]

[This Supplement to the Paper on Marbles and Limestones (vide *ante*, p. 372) is a list of some limestone quarries used of late years in public and private works, procured through R. U. Roberts, Esq., Commissioner of the Board of Public Works. Each detailed description, where possible, has the name of the Officer (in brackets) after it. This list being supplementary to the previous Paper, for the most part only refers to quarries not therein mentioned, except in those cases where, in connexion with recent buildings, the stones have been procured from some of the well-established quarries.]

ANTRIM.

Cretaceous.

Drumnasol—Drumnasol Lodge. The rock locally called *White Limestone* (indurated chalk). This rock occurs all round the coast of Antrim: it is used mainly for lime; but sometimes it is used for dressing. It is too full of joints to look well, or to stand frost (*W. Gray*).

ARMAGH.

Carboniferous.

Glasslough.—Used in the spire of Corporation-street and Carlisle Churches, Belfast; also in Robinson Villa, Cultra, Co. Down. "Of a good high colour; works freely; durable" (*W. Gray*).

CAVAN.

Carboniferous.

Rocks.—One mile from Cavan.—Surface rock; no regular quarry. Used in the Masonic Hall, Cavan (built 1885), for walling. The stone seems to be durable, and works freely. The dressings are of sandstone from Lisnaskea, Co. Fermanagh.

Ardhill.—Six miles south-east of Cavan.—School; built 1886. The local stone only used for walling and rubble; those for the dressings being procured from Crossdrum, Co. Meath.

Mount Nugent.—Drumrora School; built 1886. The stone is only suitable for walling, and is said to be durable. The dressings from Ross, Co. Meath.

CLARE.

Carboniferous.

Bushy Park.—Ennis Courthouse, in entire building; in Prison, for dressed work. Light colour; worked easily.

Rosslevin.—Ennis Prison, used with the Bushy Park stone. Dark colour.

Kilfenora.—Ennistymon Church. Dark colour; worked hard (*W. D. Williams*).

CORK.

Carboniferous.

Carriglass and *Conna.*—Carriglass School and Conna Glebe-house. Used for the rubble-work and quoins; but it is of too small dimensions for the sills of windows and doors (*A. T. Williams*).

Ballydaniel or *Pothouse.*—Ballydaniel Schoolhouse and Residence solely built of these stones. The stone has also been largely used for heavy railway works, but is not suitable for sills, or in general for ordinary building purposes (*A. T. Williams*).

Cloyne.—School. The local stone runs in small sizes; and for large scantlings the Carrickacrump stone is used.

Carrickacrump.—For the description of this well-known stone, see page 416. Mr. Williams points out that it has been extensively used in the Cork harbour and Haulbowline works.

Ballintemple. — School. This stone is another that is well-known, having been made historical by Macaulay (page 416).

Ballintubber (Kanturk).—Used in the dressings for the Church, Killarney, Co. Kerry. Light-coloured; a very superior stone.

Mitchelstown.—Between the town and the workhouse. A marble; grey; a good working stone (*J. Newstead*).

Boreenmanagh and *Haulbowline Island*, near Cork.—Reddish; slaty character; formerly used to some extent for chimney-pieces. About one mile south-west of Cork there is a vein about three or four inches thick in the ordinary limestone.

Ballyclough, near Mallow.—Reddish; hard; slaty character; suitable for flagging; formerly used a little for chimney-pieces.

DONEGAL.

METAMORPHIC CAMBRIAN? OR ARENIG?

Dunlevey.—A marble, used in Dunlevey Church for dressing, walling, and rubble. In Glenalla Church, near Rathmullen, for dressed work in the windows, doors, and buttresses. Capable of good and fine work; a superior stone, but cannot be raised in large sizes.

Ballymon.—Sheephaven Coastguard Station. An inferior marble, used in the quoins, piers, and sills; very hard to work; very durable (*J. Cockburn.*)

Glenree ("Cooskeagh Quarry"). South-west of Carrigart.—Whitish, grey-clouded, and greyish. A marble. Free and kind; durable; a good stone for inside and outside work. Used for the dressing of the Millford Union Workhouse; dressing buttresses and pulpit Glenalla Church; chimney-pieces Glenalla House; inside work Carrigart Roman Catholic Church. The fonts at Ramelton and Glenalla Churches were cut out of one block (*J. M'Fadden*).

Barnes Lower (O'Donell's Quarry). North-west of Kilmacrenan.—Greyish-blue; durable; a good stone for hammered, dressed, and rubble work. Quarry opened in 1846, when building Kilmacrenan New Church; since has only been worked for lime-burning (*J. M'Fadden*).

Carn Lower. North-east of Rathmelton.—Limestone; hydraulic.

[In this county, more than any other in Ireland, are the metamorphous limestones capable of being used for cut-stone purposes. See p. 417]

CARBONIFEROUS.

Ballyshannon (various places in vicinity).—Convent of Mercy, Ballyshannon. Hand-punched for facing and quoins; it works

freely and well. Also for internal work, with sandstone, in the Belfast Banking Co. Buildings (*J. Cockburn*).

DUBLIN.

Carboniferous.

Milverton (Skerries).—Balbriggan Coastguard Station. Used on the base of the octagon tower, sills, and dressings; also in Rockabill Lighthouse. A hard limestone, rather stiff to work (*see* description, p. 420).

Howth.—Grey; magnesian; makes good *hydraulic lime.*

GALWAY.

Carboniferous.

Angliham.—Queen's College; Model School; Parapet of the Tower of St. Nicholas' Church, all in town of Galway. Used for the sills, quoins, and dressings; works freely, and found durable.

[In this neighbourhood (Angliham), as previously mentioned (p. 425), there are acres of most superior stone. As these lie in nearly horizontal beds, they ought to be invaluable, if worked on the American principle of cutting them by machinery *in situ* in the quarries. An enterprising Company might "run a big thing in stones" from the Port of Galway for the English market, more especially as the freights from all the west coast of Ireland are low, most vessels having to leave it in ballast.]

KERRY.

Carboniferous.

Lixnaw.—Dominican Church, Tralee. A marble, close-grained, uniform texture, and capable of a high polish. Used for the moulded bases and the columns of nave.

Ballylaggan (near Tralee).—St. John's Church, Tralee. Used for the dressing in the new addition. Light-coloured, superior stone; free, durable; works out in large blocks.

Castleisland.—Roman Catholic Church. A marble capable of a high polish. Colour, light red. Used in the piers of the chancel.

KILKENNY.

Carboniferous.

Kilkenny (vicinity of).—Used in the Kilkenny Model School, Lunatic Asylum, Agricultural Museum, and other public buildings,

for punched, chiselled, or moulded work. The stone is of a good grey colour; hard and durable; it flies well before the punch and chisels to a good surface, but not so fine as that of the Ardbreccan stone, or of that of Sheephouse, Co. Meath (*M. Mellen*).

Ballykilboy and *Strangs Mills.*—Waterford City, in the Government offices and public buildings. Granite and limestone dressings in both buildings worked freely (*W. D. Williams*).

LEITRIM.

Carboniferous.

Carrick Klevy Station.—Carrick-on-Shannon Roman Catholic Church. Durable; squares well under the hammer. For chiselled work the stones were brought from Lanesborough and Creeve, Co. Longford.

LONGFORD.

Carboniferous.

Creeve. Near Longford.—Used for dressings in the Roman Catholic Church, Carrick-on-Shannon; in the Bishop's Palace, and in the Asylum, Mullingar; in the Crummy School, half-way between Carrick and Ballinamore, Co. Leitrim; and in Cloonmorris School, between Dromod and Newtown Forbes.

Lanesborough.—For dressings used in the Ballymahon School; in the Roman Catholic Church, Carrick-on-Shannon; and in the new Convent, Sligo.

Ballymahon.—Very brittle; hard; difficult to work; durable. Used for rubble in the National School.

MAYO.

Carboniferous.

Moyne (Ballina).—Used for dressing and walling in the Roman Catholic Cathedral, Ballina, and in various buildings, both modern and ancient, as given in the descriptions of the Mayo quarries. "Works freely; found durable; but weathers of a bad colour" (*R. Cockrane*).

MEATH.

Carboniferous.

Ballymadrin. Three miles from Ratoath.—Is fairly good and durable. Used in the walling of Ratoath Dispensary; built in 1886. The stones for the dressing procured from Crossdrum.

Stirrupstown. Near Crosskeys.—Hard, and only fit for scabbled work. Used for walling in the neighbouring Constabulary Barrack. The stones for the dressings were procured from Crossdrum.

Ross.—This well-known stone is very generally used for cut-stone purposes in various parts of Ireland (*see* description, p. 436).

Crossdrum.—Another well-known stone (*see* description, p. 436).

QUEEN'S CO.

Carboniferous.

Stradbally and *Ballullen.*—Maryborough Churches, Prison, and Asylum; Mountmellick Churches and Convent. In Abbeyleix Churches, with Slieve Bloom sandstone; both being used in the dressings (*W. D. Williams*).

ROSCOMMON.

Carboniferous.

Carrowroe. Two miles from Roscommon.—Works pretty freely; is durable. Used for walling and rubble in the new Convent, Roscommon. The stones for the cut-work were procured from Lanesborough, Co. Longford.

SLIGO.

Carboniferous.

Ballysodare.—A uniform stone; works well into mullions and tracery, and is durable. Used in St. John's Church, Sligo, in the new east window, vestry-room, and organ-chamber (*R. Cochrane*), and in the Roman Catholic Church and Presbytery for both dressed work and rubble.

Scarden. Three miles from Sligo.—Hard and flinty; durable. Used for rubble and the pitched faces of the walls in the Town Hall, Sligo. The dressings are of sandstone, from Mount Charles, Co. Donegal.

Carrowroe. Two miles from Sligo.—Works pretty freely; is durable. Used for walling and rubble in the new Convent, Sligo; the stones for the dressing being procured from Lanesborough, Co. Longford.

[In the hills to the north-east of this county there ought to be excellent limestone for all dressed purposes; as, however, there are no quarries opened, they send to great distances for stones for dressing and other cut works.]

TIPPERARY.

CARBONIFEROUS.

Ballinillard.—Tipperary Town Churches. Appears to have worked freely.

TYRONE.

CARBONIFEROUS.

Omagh. Vicinity.—Used for rubble in the Military Barracks. The sandstone used for quoins and dressing is of an inferior quality, being the stone known as the "Red Beds" from the Gortnaglush quarry, near Duncannon, which is easily worked, but is not durable (*J. Cockburn*).

WATERFORD.

CARBONIFEROUS.

Whitechurch.—As dressings in the Churches, Dungarvan, and Lismore Castle.

Shorough.—Lismore Roman Catholic Church, with sandstone dressings (*W. D. Williams*).

WESTMEATH.

Carboniferous.

Cullion. Two miles from Mullingar.—Rather hard and splintery for chiselled work; very durable. Used in the Bishop's Palace, and in the Asylum, Mullingar, for walling, rubble, and part of the dressed work; but in both buildings most of the stones for cut purposes were procured either from Creeve (*Co. Longford*), or Ross (*Co. Meath*).

XLVIII.—ON THE LIASSIC FOSSILS OF M'CLINTOCK'S EXPEDITION. By REV. DR. HAUGHTON, F.R.S.

[Read, January 19, 1887.]

The following correspondence throws further light on the fossils found by Sir Leopold M'Clintock at Wilkie Point, Prince Patrick's Land [lat. 76° 20′ N.; long. 117° 20′ W.], and described by me in this *Journal* (vol. i., pl. ix.)

The letters sufficiently explain themselves, bearing in mind that I had originally stated my opinion that the fossils were of Jurassic age (probably Liassic.)—S. H.

N.B.—These fossils were presented by Sir Leopold M'Clintock to the Museum of the Royal Dublin Society, and can now be seen in the Science and Art Museum, Dublin.

"Geological and Natural History Survey,

"Museum and Office, Sussex-street, Ottawa,

"*5th November*, 1886.

"Dear Sir—In endeavouring to work up a small general Geological Map of the Northern part of the American Continent, which may be published in connection with our reports, I have had frequent occasion to refer to your Appendix to M'Clintock's Voyage, which gives, I think, practically all the facts available for the northern portion of the Arctic Archipelago.

"I have not access to the earlier Papers in the Journal of the Royal Dublin Society, but presume the Appendix (edition of 1860) may contain a sufficient *resumé* of the whole.

"The point on which I take the liberty of addressing you, particularly at the present moment, is the character of the fossils described as Liassic, and figured in the *Journal of the Royal Dublin Society*, vol. i., pl. ix.

"Is it possible, in your opinion, that these fossils may indicate a horizon the same with that of the so-called 'Alpine Trias' of the western part of North America? From the occurrence of a Monotis, western analogies would rather tend to this view of the case, which, however, the fossils themselves may be sufficient to disprove. If not troubling you

too much, I should be glad to have the benefit of your views on this subject. The Fauna of the 'Alpine Trias'—which occurs high up on the west coast—is well illustrated in Exploration of 40th Parallel, vol. iv., plates 10 & 11, and in Palæontology of California, vol. i., plates 3–6.

"Yours truly,

"GEORGE M. DAWSON.

"Rev. Prof. S. Haughton, F.R.S.

"Prague,
"31*st December*, 1886.

"My dear Ball—You must excuse me that I did not answer your kind letter earlier, but it had somehow miscarried, so that I received it about a fortnight later than the book.

"The fossils about which you wish to have my opinion have aroused curiosity already on several sides, and about a year ago Professor Neumayer, of Vienna, sent me a number of plaster casts of the species, taken from the originals at Dublin, to ask my opinion about them.

"As far as I can judge the matter, it seems to me that there cannot be much doubt that *Ammonites M'Clintocki* is a Jurassic species, but rather of middle Jurassic than of Liassic affinities. This opinion has also been expressed by Neumayer in the Denksch. d. Kais. Acad. der Wissensch., Vienna, vol. i., Die Geographische Verbreitung der Jura Formation, p. (141), 1885, where the species is redescribed and figured.

"The Avicula that has also been found at the same localities might be Triassic, but just as well it might be Jurassic, and there can be drawn no conclusion from that species. So, on the whole, the probability remains that in these high latitudes Jurassic beds are exposed.

"The Triassic species described by White from Idaho, in his Contributions to Palæontology, and later on in the 40th Parallel Report, are quite different things, and only the Avicula show at all any similarity. Such a similarity is, however, of no value whatever.

"Very sincerely yours,

"W. WAAGEN.

"V. Ball, M.A., F.R.S."

XLIX.—NOTE ON SUBMERGED PEAT MOSSES AND TREES IN CERTAIN LAKES IN CONNAUGHT. By A. B. WYNNE, F.G.S.

[Read, March 23, 1887.]

The object of this communication is to place before the Society a few observations upon what might be regarded as evidences of relative changes in the level or superficial distribution of land and water in the regions referred to.

There are, doubtless, several cases besides those to which I shall refer, wherein peat bogs, with trees of a former period, are to be found permanently submerged in various parts of the country, and in present conditions totally different from those under which these trees and growths flourished. It will be sufficient, however, to take the instances of the basin of Lough Arrow, a few miles from Boyle, and of the River Garwogue, connected with and running from Lough Gill, through the town of Sligo.

As far as regards present circumstances, the basins of both of these lakes are extensively encumbered with "drift," and the water is retained, in both cases, practically in rock basins: that is to say, river action has denuded the drift in the direction of outflow, and the surplus water escapes over beds of the solid carboniferous limestone of that country, lying in a nearly horizontal position, or undulating at low angles. In both cases the margin of the water is formed here or there by rock, drift, or the ordinary bogs of the country, the latter indicating, perhaps, a formerly wider extension of wet, swampy ground around these lakes or of their own proper areas.

The River Garwogue leaves Lough Gill as a broad, sluggish stream, until its rock-bar is reached at Ardachowen. Thereafter the stream becomes more rapid, falling some twenty feet in the short distance between Ardachowen and the tideway, which enters the town of Sligo as far as the Victoria Bridge. The last reach of the comparatively still water, just above Ardachowen—one of the most beautiful parts of that picturesque locality—is underlaid from side to side by peat, with numerous trunks of trees. It is plain

that the water here could never have escaped at a lower level than that of its present retaining rock-bar, so as to permit of the sunken forest trees having flourished in the air, without the supposition of earth movements having taken place since the peat and trees occupied the subaerial surface, movements which had considerably altered the position of the ground to be drained with regard to previously existing levels.

Further seaward, along Sligo Bay, there are indications, in raised beaches, that an upward movement of the land took place; and I found, many years ago, shells of the common sea mussel in a sand-pit, not far from the old coach-road between Sligo and Ballysodare, upon part of the high drift-covered ground lying between Lough Gill and Ballysodare Bay. In these cases the indication is of an elevation in recent times, which might here or there pond back the terrestrial water, but which must have had regions of singularly local intensity, if it can be at all supposed to have caused limited land spaces to become permanently submerged, as in the case near Ardachowen, on the Sligo river.

Turning now to Lough Arrow, near Boyle, we find this to be a large lake, with irregular outline, four and a-half miles in length, by a mile to two and a-half miles in breadth, bordered by hog-backed hills of drift near its margin, similar hills forming islands within it, while it is surrounded by nearer, or more remote, mountainous elevations, such as the Geevah Hills, formed of coal-measures, on one side, or the carboniferous limestone elevations of Knocknahorna and Kesh, on the other, or the termination of the pre-carboniferous Curlew Mountains towards the upper, or Boyle end of the lake. The lake itself is peculiar in having no rivers to supply it beyond the little brook from the Curlews, which empties itself into it at Ballinafad. The lake water is clear, and is probably largely supplied by springs, seeing that a considerable stream issues from the lake, passing over a rock barrier near where it starts, at Annagh or Ballyrush, and eventually reaching the sea at Ballysodare. Another peculiarity is that this large lake is at one point separated by a distance of only a few hundred yards from Lough Key, one of the lakes of the basin of the Shannon, with which that of Lough Arrow has no connexion.

The shores of Lough Arrow, where not formed of drift, are in various places composed of peat, locally known as "The Black

Banks," particularly around the deeply-indented bay called Lough Brick, and at the lower end of the lake about Ballyrush, Annagh, and Castlebaldwin. Where this is the case the bottom of the lake is often also formed of peat with trees, while in other places huge masses of the local rocks washed out of the drift, like that called the "Rock of Muck," on the Annaghcloy shore, may be seen, scattered over the bottom, through the clear water, when this is calm. Under similar circumstances, off the point of Aughanah, on the property of Colonel Ffolliott, where the almost horizontal limestone comes to the surface of the lake, at the shoal called the "Quarries," or the "Flag of Aughanah," one can see, down beneath the lowest level to which the water ever falls, the stools and stumps of large trees, so thickly accumulated in places, that when in the little strait between "The Slab" and the point, boatmen exert more than usual caution to avoid "snags." Most of the trees appear to be in their position of growth, with, in some cases, but little, if anything, intervening between them and the limestone slab on which they rest.

Here again the case recurs that the lake could scarcely have stood at a lower level while its escape lay in the present direction, on account of its retaining rock barrier; and the conditions which would have placed these trees in their natural subaerial position, would require either the occurrence of earth movements of subsequent date, or such a balance between the supply of lake water and its exhaustion by means of evaporation, that the water should be maintained at a lower level than at present, when of course the lake could have had no river outlet at all.

I have been acquainted with both of these lakes since childhood, and I have repeatedly visited Lough Arrow at the season of the Ephemeral June Carnival of *Salmo ferox.* Lough Brick, of which I have spoken, was, within my memory, almost a small separate lake, partly surrounded, and nearly divided from Lough Arrow, by bog banks. Through a gap in these banks a boat could just pass; but the banks have since been almost entirely washed away—one islet remaining near where the gap was, on both sides of which boats can pass freely now.

On Captain Gethin's property at Ballindoon, towards the other end of the lake, there is a small recess in the boggy bank of the lake, called "Poolnaperches." Here a projecting promontory of

peat bore some trees of considerable size. The promontory became an islet, and this has been washed away by the waves of the lake, on which I have seen a heavy sea often rise as rapidly as has been noticed in many other lakes all over the world (from Lough Gill to the Lake of Kashmir, or in the opposite direction).

Now, taking this wasting by wave action of the boggy margin of the lake into consideration, in discussing the problem of the sunken trees with Captain Gethin's steward (Sergeant Ross), whilst fishing off "Poolnaperches," one day last summer, he seemed to me to hit upon an explanation which would account most satisfactorily for the submerged forest trees of Aughenagh Point, and may be capable of a wider application in many similar cases of such submergence. We both observed that the stools of the old, as well as those of the modern, trees in these bogs, spreading their roots horizontally, retained their position thus until the boggy ground they grew in had been almost entirely removed. Deprived of the leverage which their stems—previously broken off—would have given, they had less to disarrange their natural pose; and thus, when some storm of greater force than usual acted, the retaining roots snapped or drew, and each water-logged mass subsided to the bottom, settling upon its broadest surface, still in its natural position of growth; so that afterwards, looking down through the water, the trees would appear to have grown where seen, though entirely beneath the water of the lake, and associated in cases with a recomposed peaty deposit.

As to the extent to which this action may have affected the shores of Lough Arrow, Sergeant Ross further stated that, under a particular effect of light, upon a stormy day, he had seen from Ballindoon House, which stands high upon one of the drift hills, a long, dark channel, reaching sinuously from the river at Ballyrush through the middle of the lake, between Ballindoon and Bell's Island opposite. The lake, at its lower end, from one side to the other across this channel, appears to have both boggy banks and a boggy bottom. Hence it is not improbable the channel he saw may have marked a former bed of the river, before the bog on each side had been eroded away; and the definition of this channel may have been aided by the storm having disturbed the marly substratum that not unfrequently underlies our Irish bogs.

I am not quite prepared to say how far these observations may

account for the supposed submergence of peat mosses, with forest trees, in *all* cases in inland lakes of the West of Ireland; but the explanation seems to be capable of affording a satisfactory solution of the question regarding Lough Arrow and the Sligo river, without making any unnecessary overdrafts upon possibilities as to local or considerable earth movements at very recent periods, and even though it may deprive the subject of a certain halo of mystery—if I may be allowed to adapt to this subject the well-known lines of our national Bard—it would supply some answer to an inquiry frequently made:

> "When on these waters the fisherman strays,
> Or becalmed in his boat reclining,
> He sees the old forests of other days
> In the wave beneath him shining."

L.—LISBELLAW CONGLOMERATE, CO. FERMANAGH, AND CHESIL BANK, DORSETSHIRE. By G. H. KINAHAN, M.R.I.A., Etc. (Plate XII.)

[Read, March 23, 1887.]

It would appear that the process of formation, and the agents at work during the accumulation of the "Lisbellaw Conglomerate," have been a puzzle to those who have examined it, or rather to those who have published the results of their examination.

It ought not, however, to be so hard to understand, as similar accumulations are due, not only to the artificial groynes erected on beach-lines, but also to natural groynes, as they occur on the south-east coast of Ireland. As the accumulations due to groynes, artificial or natural, seem not to have been studied by those observers, it may possibly be allowable to give an epitome of the effects due to them, and their general characters.

In general, artificial groynes are placed as near together as to form a continuous permanent shingle beach; and if they are judiciously erected, that is, raised plank by plank as they fill, much in connexion with the present inquiry cannot be learned from them.

But in many places on coast-lines more or less isolated groynes have been put down to project individual portions of a coast-line, as is the case in places along the coast of Waterford. From such individual groynes we learn, if we follow the "flow-tide" stream towards the groyne, that the accumulations gradually become wider, and, in general, the materials coarser, till at the groyne there is a massive shingle accumulation. This seems to be invariably the case on the coast of Waterford, and also in various places on the English coast; but in other places, as presently mentioned, where the tidal-drift is solely a fine sand, the accumulation, although it will increase in bulk, yet the sizes of the materials will not do so. On the down-stream side of a groyne, like those on the beaches of Waterford, the accumulations will be small in dimension, and the material composing them much finer than those on the up-stream side.

On the coast of south-east Ireland (Co. Wexford), as the normal drift of the county for a large part is fine sand, the drift due to the "flow-tide" current is in general of a similar character; and the big accumulations on the up-stream side of the groyne are in general sand. This, however, is not the case in the beach to the north of the Blackwater. Here, to the north-east, Cahore Point acts as a groyne, and south-west of it, at the head of the current from the Blackwater, there is a shingle beach. This is somewhat like the "Lisbellaw Conglomerate," gradually down-stream becoming coarser and larger, but dying out before the extremity or point of groyne is reached. The reason for the ending of a shingle beach before it quite reaches the natural groynes is due to the "on-shore, or half counter-tide currents." As this has been previously explained in different Papers already published, it is unnecessary to again repeat it.

There is, however, a much more parallel accumulation in that of the Chesil Bank, Dorsetshire; although what is now taking place at the latter is on a much larger scale than the work done in Silurian times at Lisbellaw.

The Chesil Bank travels eastward along the shore of Lyme Bay, with the "flow-tide" current accelerated by the prevailing winds from the westward, to be stopped by the natural groyne—Portland Bill. If this beach is followed from the west eastward, the accumulation gradually increases in size, and also in the dimensions of the materials, till eventually it forms a mass of more or less coarse material to the westward of the Bill. But, on the other hand, in Weymouth Bay, eastward of The Bill, the accumulation is at a minimum, and of fine materials.

As may be seen in the accompanying diagrammatic plan (Plate XII.), the relation between the adjuncts of the Chesil Bank and, on a smaller scale, those in connexion with the "Lisbellaw Conglomerate," is very similar, except that while the "flow-tide" current in the first set from the west eastward, that in the Silurian sea must have ran south-westward.

To the north-eastward of Lisbellaw, in Silurian times, there was a shore-line trending north-eastward, and immediately west of the village a spit of *Ordovician* land, somewhat like the Portland Bill, while westward of this spit was a bay that may be compared with Weymouth Bay.

The Silurian beach that accumulated along the north-east and south-west shore-line has similar characters to that on the north shore of Lyme Bay; that immediately west of the north end of Lough Eyes, being of small dimensions and finer materials, while, as it is followed south-west, to Lisbellaw, it increases in bulk and the size of the materials. This beach, as it is now much overlapped by the newer carboniferous rock, cannot be entirely seen; but it seems to end suddenly before the point of the Ordovician land is reached, while westward of that spit of land the Silurian rocks are of quite a different character, being sandstones and shales. Thus there is more or less a very complete similitude between the two. As in each case there is a breach gradually getting larger and coarser, till it nearly reaches the point of the groyne, where it ends; while at the other side of the groyne the accumulations are at a minimum, and of a much finer character.

LI.—IRISH ARENACEOUS ROCKS—SANDS, SANDSTONES, GRITS, CONGLOMERATES, QUARTZ-ROCKS, AND QUARTZYTES. By G. H. KINAHAN, M. R. I. A., Etc.

[Read, March 23, 1887.]

CONTENTS.

INTRODUCTION.

A STUDY of the history of the Irish sandstone rocks is interesting, they seemingly having been the favourites with the early builders. The primitive inhabitants of the country appear nearly invariably to have utilized the hardest stone nearest at hand, so that in many places they used the granite erratics; but in such places where there were both granite and sandstone erratics, they seem to have chosen the latter; while, if the rock had to be quarried, it was nearly always the sandstone that was selected.

After stone with mortar was introduced, at first sandstone still seems to have had the preference in the districts in which it occurred, except in a few places where there were good slate-rocks; as these, in certain localities, were extensively used, and are still used, for architectural purposes. This, however, will be more particularly mentioned in a subsequent paper on *Slates and Clays.* It may, however, be here mentioned that some of these slate-rocks, although producing good and durable work, were not at the same time capable of giving the fine and embellished cut-work to be found in the granite, limestone, and sandstone structures.

Later on, as has been pointed out by Kane, Wilkinson, and others, the sandstone was superseded by limestone, the latter rock having been often carried for great distances into the sandstone areas. This probably was due in a great measure to the workmen, who had a preference for the stone to which they were accustomed. Various examples in modern time in support of such a supposition are on record. When the Scotch workmen were building Muckross Abbey, Killarney, about forty years ago, they ignored the excellent limestone of the neighbourhood, and imported sandstone from Chester, that being the nearest place where they could get sandstone similar to that with which they were accustomed; and in different places, the engineers of the Ballast Board, when building lighthouses, have brought Dublin granite to the different localities. This may be seen, besides, in various other places, at the West Sound into Bearhaven, Co. Cork—a locality famous for its good sandstone. Kylemore Castle, Co. Galway, was contracted to be faced with granite, and although the locality

is on the edge of the great granite tract of Galway, yet the contractor elected to bring the stone from Bullock, Co. Dublin—a stone he was accustomed to. We find also the same thing in earlier times. The Normans, for dressing and other cut-stone purposes in their castles and cathedrals, brought from their native country, Caen-stone into England, while their descendants, the Anglo-Normans, did the same in regard to Ireland.

[It seems to be the general opinion that there is no home stone at present in the market equal to the Caenstone for fine inside work; but during the late restoration of Christ Church Cathedral, Dublin, some of the old cut-stones (A.D., 1008) were found, which the architect seems to have insisted were "Caenstone." But the builder (Mr. Sharpe) was not of this opinion, and, after considerable research, he was able to prove that the stone was procured in a once famous quarry at Eyebridge (?), about twelve miles from Glastonbury, Somersetshire. He visited the place, and the stones seem to have been brought from the quarries by a canal, the remains of which can be traced. From Mr. Sharpe's practical knowledge he is convinced that this stone was used in Mellifont Abbey, Co. Louth; St. Mary's Abbey, Dublin; and St. Kevin of Glendalough, Co. Wicklow—stones which in general are supposed to be Caen-stone. Mr. Woodward, the author of the *Geology of England*, in reply to inquiries, states:—"The stone you inquire about must be the Doultery stone, east of Shepton-Mallet; used largely in the construction of Wells' Cathedral and Glastonbury Abbey.]

But the pre-Anglo-Norman builders in Ireland, as already mentioned, as also many of the early Anglo-Normans, used the native sandstone. It is conspicuous in different places, as hereafter mentioned, that although the local sandstone used in building of the earlier structures was good, yet all the later structures are built of limestone brought from a greater or less distance.

Other reasons for the introduction of limestone may have been that the builders early understood the crushing stones were capable of bearing,[1] and were aware that if a column in a building was to be massive, they might use sandstone; while if the column had to be slender, and at the same time support an equal weight, limestone was preferable. This is illustrated, as pointed out by Wyley, in the small limestone columns of Jerpoint Abbey, Co. Kilkenny.

They also must early have learned that limestone could be more finely, more easily, and more cheaply worked than the

[1] Yet Wilkinson specially points out that some builders had no such knowledge, and illustrates instances in which buildings had failed through the want of knowledge as to the crushing the stone would bear.

ordinary sandstone of the country, many of the latter requiring the tools to be frequently sharpened.

Although the strength of the limestone, and the facility by which it could be worked, may have led to a preference for it, it should also be remembered, that as the country became occupied by foreigners, the chief centre of the population—that is the towns—were principally in the plains, or the valleys, on the limestone areas, and the artificers, becoming cunning in the working of limestone, preferred to use it, even when they had to transport it a considerable distance. In many places, however, they had water-carriage ; that made the transport comparatively easy and cheap.

Or the use of limestone may have been due to fashion. At the present day many rich men will only use a stone his poorer neighbour cannot procure. This seems to have been a mania in remote ages as well as recently, and not without a certain value, as in many places the old buildings are pointed out as "not having in them a stone to be got in the whole country," while in modern times Rothschild's French Chateau has brought him historical fame on account of the English stone and workmen used in its building. Elsewhere on the Continent, in America, besides in the home countries, buildings are pointed out, not for any architectural beauty, but solely to record that the stones in them were brought from a great distance, and at great expense.

The mania for foreign stones appears to have been very prevalent in Ireland at the beginning of the present century, as in the majority of the buildings erected between 1800 and 1840 the stones for the dressed work were imported. This is very conspicuous in Dublin, as hereafter exemplified in the list of places from which the sandstone used in its principal buildings was procured.

As previously pointed out, the early builders, in most cases, seem to have selected stones on account of their durability ; but at the present time there seems to be, in many cases, a running after stones—not on account of their durable qualities, but that they can be easily worked, and are therefore cheaper.

[The Ballycastle stone, Co. Antrim, if it had been well selected, everywhere gave good and durable work ; yet, at the present time, in the neighbouring towns it is in disrepute, while inferior sandstones are used solely because the first-cost is less. This apparently is false economy ; for although the first-cost may be less, yet the after

redressing, or painting, or otherwise doctoring of the stones induce expenses which in a short time eat up any little saving there may have been at the first in using inferior material. This can also be seen in different places in Dublin, which need not now be mentioned, as this subject will be alluded to further on.

In general, sandstone now in use, except the Caenstone, does not appear to be capable of receiving as minute work as limestone. However, if we examine the old structures, we find in some of them beautiful and elaborate work, but in such cases the stones are much harder than those now in request. The exquisite doorway of Maghera Church, Co. Derry, cut in the local stone, is so durable, that the brushing of the tools can still be seen; but this stone would not now be looked at, being considered "too hard."

According to the records, as left by our ancient buildings, it would appear that the soft and more easily worked limestone, sandstone, and granite, are best for inside work; but if the work is to be exposed to weathering, the durability depended on the quartzose nature of the stones, they ranging in the following order—quartzose sandstone, quartzose limestone, and quartzose granite. The sandstones, apparently, taking in our climate the first place.

There are, indeed, in a few places very quartzose granites and limestones of a high order, but they are exceptions to the general rule, as the majority of our best preserved old work nearly invariably is in sandstone. Outside these groups there are, however, some stones, but not very commonly met with, that show durable work, such as the Camstone, and some of the basalts.

Quartzose stones, when dry, nearly invariably are difficult to work. This is the case with the "Park stone," Wexford, which, when worked in its "quarry water," as exemplified in Roche's Churches, turns out good work. Our ancestors may have understood this peculiarity in the stones, or it is possible they may have overlooked first-costs, and speculated solely on the subsequent durability of their work—they working in hard stones that now would be condemned.

[Some sandstones which occur not uncommonly in the Carboniferous formation have a latent silicious or carbonaceous cement, and when newly raised, and in their quarry water, are soft and easily worked, but subsequently, when dry, they become as

hard as a silicious grit. Some stones contract considerably during the drying, and stones of this class, before being used, ought to be given time to dry and contract, as otherwise they will dry unevenly, and show not only unsightly open joints in the work, but are also liable to cause uneven settlements.]

The cements of the sandstones are silicious, calcareo-silicious, and argillo-silicious. Usually in a contrary order they cut the more easily, while their durability is the reverse, except in some cases, that is, where they are micaceous, as many such stones, otherwise good, are not durable.

Other examples of well-preserved sandstone carving, besides the previously mentioned doorway at Maghera, Co. Derry, are exemplified in the doorway at Killeshin, Co. Carlow, cut in the local coal-measure sandstone; in the massive and beautifully carved crosses at Monasterboice, Co. Louth, the stone being a clean-grained silicious sandstone. St. John's Gate, Drogheda, in the same county, was built of mixed limestone and sandstone, and it exemplified the unequal weathering and durability, the latter being perfect, while the others have decayed considerably: it must, however, be allowed that the limestone was of a very bad class. The dressed work at Mellifont shows the durability of the sandstone. In the latter the bad effects of mica is also exemplified, the micaceous sandstones that were used having sadly weathered.

[The old ruins at Mellifont, during the late repairs under the Board of Works, had the rubbish removed, and, as pointed out by Mr. Lynam, County Surveyor, the sandstones thereby re-exposed have rapidly weathered. This I have observed elsewhere, not solely in regard to sandstone—as the stones in different ruins, when exposed to the drying effect of the atmosphere, have rapidly decayed. This may be seen, as well as elsewhere, at Devenish, Lough Erne, where the re-exposed sandstones have suffered, and in St. Kevin of Glendalough, Co. Wicklow, where many of the old disentombed sculptured schist slabs have, in a few years, been greatly defaced. A cupped stone, now in "Saint Kevin's Kitchen," when first raised, had all the tool markings; but these were obliterated by its being allowed to weather for a year. It may appear remarkable that stones, when in their natural saturation, that is, having their "quarry water," harden when exposed, while stones subsequently saturated, when dried, decay. To explain this, it may be suggested that the first water, that is, the "quarry water," was in combination with either silica or carbon, the mineral matter consolidating as the water evaporated, while in the subsequent saturation, the moisture was solely water that had saturated the pores and other vacancies in the stone, thereby absorbing the cement, and when this water with the absorbed cement was withdrawn, it left the stone more or less a friable mass—at least as far in depth as the absorption had effected it.]

In Boyle Abbey, Co. Roscommon, the stone shows excellent work; it is also durable, as in places it still retains the tool markings.

[In America, and also in England, many stones, even when in the quarry, are sawn, or otherwise worked and sculptured by machinery; very little work, however, of this kind goes on in Ireland. In some workshops there is sawing and planing; but there does not seem to be a quarry in which the stones are cut *in situ:* while if a building is in progress you generally hear the hammer and chisel, and not the saw or plane, at work. However, saws, at least, were known to the early Irish builder as in many of the ancient structures the stones, especially sandstones, were sawn, not chiselled. The only instance that I can learn of saws being used to cut stone *in situ*, was in the Angliham marble quarry, Co. Galway, where, somewhere about the year 1860, Mr. Abbott erected a sawing-frame and engine; but when the block was about half cut through, the saws broke off, leaving, as Mr. Sibthorpe points out, a puzzleite for future geologists to explain how parallel narrow seams of oxide of iron occur in the blocks.]

On reviewing the records of the different Counties, it is conspicuous in how many places the sandstones or conglomerates were wrought into millstones. In some places there was a large trade not only for home but also for English uses. This trade, however, seems to be altogether a thing of the past, as nowhere, as far as we can learn, is it now followed. The manufacture of stones for flax-crushing necessarily died out when the new modes of crushing, or manipulating, were introduced; but the decline in the demand for corn millstones seems to have been solely due to the repeal of the Corn Laws, which starved out the industry, and caused it to be abandoned. Since then the few stones required are imported, principally from France. At the once famous quarries of Drumdowney, Co. Kilkenny, there has not been wrought a pair of stones since 1875, and then only one pair.

To some of the good class sandstones not now in request, as those near Thurles and Dundrum, Co. Tipperary; Doon, Co. Limerick; and others mentioned hereafter; public attention may be specially directed.

[When the modern sandstone buildings are tabulated, it at first appears remarkable that so many, even in towns at great distances from one another, are all built of stones from one quarry. On inquiry, this appears to be due to their having been built by one contractor, or under the orders of one architect, the contractor or architect having an interest in, or liking for, a certain stone. In Dublin, many of the recent Insurance Offices have in them the same stones, they all having been built by the one contractor. But this is more conspicuous in the country towns, especially in the Banks—as the

offices of one company through a large range of country will all be built of one stone, while in all those belonging to another company a different stone is used; the stones often being brought from a distance, although better stones could be procured in the vicinity.]

GEOLOGICAL EPITOME.

The Arenaceous rocks range all through the different geological groups. It is therefore expedient, before entering into detail, to give an epitome of the present state of Irish Geology. In this the classification of the groups is that adopted in the TABLE OF STRATA in the first Paper of this series on Irish Economic Geology (*ante*, "Metal Mining," p. 204).

CAMBRIAN AND ARENIG.

[These groups are so mixed up as to necessitate their being described together.]

From the latest fossil evidence brought before the public, which is, that supposed Arenig type fossils have been found in the gneiss and schist series at Fintown, it would appear that it is now incontestably proved that the oldest rock in Donegal cannot be more ancient than Cambrian. Consequently, all the other similar rocks in Ireland, which some have called Laurentian, are probably of the same age or younger: that is, these metamorphosed rocks must be the equivalents of either the Ordovician, Arenig, or Cambrian.

In 1862 Jukes, and in 1863 Sterry Hunt (after Laurentian rocks were proved to exist in Scotland), suggested the possible Laurentian age of the Donegal gneiss. In 1865 Murchison announced the existence of Laurentian rocks in the Twelve Pins (*Bennabeola*), Connemara, Co. Galway; but immediately afterwards he withdrew this statement. In the *Geology of Ireland* (1878), and subsequently in various Papers read before the Royal Irish Academy, the Royal Dublin Society, and the Royal Geological Society of Ireland, I pointed out that some of the metamorphic rocks of Donegal, Antrim, Tyrone, Leitrim, Sligo, and Mayo were probably Cambrians, but possibly Laurentians; while Dr. Hicks immediately afterwards suggested that the rocks called

by me Cambrians in the Co. Tyrone were possibly Laurentians; and this was followed by Dr. Callaway, who, in 1881, stated that patches in my Cambrians, Co. Wexford, were Laurentians. Subsequently came Dr. Hull, who seems to consider that all the tracts of highly metamorphic rocks, except those in Wexford previously claimed by Dr. Callaway, are of Archæan age ("Laurentian Rocks in Donegal and Elsewhere in Ireland," *Trans. Roy. Dub. Soc.*, vol. i., ser. ii., p. 245). It seems remarkable that, while the rocks of the Mullet, in North-west Mayo, are included in this Paper, those of South-east Wexford should be left out, more especially as the rocks in both localities are lithologically, microscopically, and apparently stratigraphically similar, if not identical.

The Wexford rocks claimed by Dr. Callaway to be Laurentians are, as he has described them, "*a mosaic of irregular fragments*" (!) protruding into a tract of undoubted Cambrian rocks, as proved by their fossils. Nowhere else in the world have the Laurentian rocks appeared after this fashion, and I do not believe in their existence in the Co. Wexford, as the so-called Laurentians are only metamorphic intrudes of Igneous rocks and their associated tuffs, similar to the intrudes found elsewhere in every group of Irish strata, from the Carboniferous down to the Cambrian.

[From Dr. Callaway's Paper, "Metamorphic and Associated Rocks South of Wexford" (*Geol. Mag.*, Nov., 1881), it is evident that the writer had my memoir, but, at the same time, that the maps he was consulting were those published some quarter of a century prior to my being in the county or my examination of the rocks. How anyone could possibly imagine that my description was that of the obsolete maps is hard to conceive; more especially as on these maps are printed the dates of their publication and the names of the Surveyors.]

The Galway metamorphosed rocks that are said to be Laurentians are undoubtedly the equivalents of the English Ordovicians, as proved by the fossils in the unaltered portions. This will be more fully discussed when treating of the rocks of that county, while the supposed Laurentian gneiss of the Co. Donegal ought now to be disposed of, if the markings exhibited by Dr. Hull at the British Association Meeting, 1886 (*Birmingham*), are Arenig types of graptolites, which there now seems to be every reason for supposing; for if this be so, it unquestionably proves that the gneiss of Donegal, which is part of the same series, cannot possibly be more ancient than Cambrian: that is, these rocks must be the

equivalents of the rocks of the groups suggested by me in 1878, in my *Geology of Ireland.*

In the Co. Galway there are no rocks that can possibly be of Laurentian age, and the same thing may now be said of the Co. Donegal. It is, therefore, only sensational geology to say that in the intervening area (Mayo, Sligo, Leitrim, and Tyrone) there are Laurentians, more especially as the metamorphic rocks therein found are lithologically, and apparently stratigraphically, identical with the rocks in Galway and Donegal. In the descriptions of those counties in which Laurentians are stated to exist more special details will hereafter be given.

[As it has been assumed in some of the official memoirs that the existence of Archæan rocks in Ireland has been proved, this subject has to be more prominently mentioned than would otherwise be necessary. This recent finding of Archæan has been very sensational from the first. Up to the end of 1880 Professor Hull insisted that my classification was probably wrong, as the oldest rocks in Connaught and Ulster were proved by the work of the Survey to be of Lower Silurian (*Ordovician*) age. But in January, 1881, *when Drs. Hicks and Callaway suggested that some of my Cambrians were Archæan,* quite suddenly Professor Hull discovered Laurentians in Donegal and elsewhere in Ireland. After seven years of steady work in the Counties Galway and Mayo, I classified the older rocks, and subsequently traced them from Mayo into Sligo, Leitrim, Donegal, and Tyrone. The rocks of the Twelve Pins (*Bennabeola*), Co. Galway, are lithologically more similar to the Huronians of Ontario, Canada, than the rocks in any other place in Ireland. These are the rocks which, after *Eozoon Canadense* had been found in them, Murchison at one time suggested might be Laurentians; but the rocks in the same county, said by Professor Hull to be of Laurentian age, are evidently the youngest in this part of Galway, and in the westward portion of his area, where some of the rocks are very little altered, fossils possibly may at some time be found, for as yet they have not been properly searched. The rocks of the Slieve Gallion district (Co. Tyrone) and those of the Pettigoe district (Counties Fermanagh and Donegal) are partly like those of Ontario, but in them are not found the calcareous rocks so well represented in Bennabeola, Co. Galway. There are also other rocks in Donegal that are partly like the Ontario rocks, such as those in the long tract embracing the Gartan Lakes (*Loughs Beagh* and *Akibbon*), and extending from them north-easterly by Lough Keel to the south end of Mulroy Bay—bits in which area are very similar to Ontario and Assinaboia, as seen north of Lake Superior. The rocks of Crann Mountain, Co. Wexford, are also somewhat like. As to the gneissose rocks, those of Galway, on the north of Galway Bay (which evidently are metamorphosed Ordovicians), are lithologically more like the Laurentians of the Dominion and the States than any other rocks in Ireland, if we except some small patches of very limited extent in Mayo, and perhaps little bits in Sligo and Leitrim; but the gneiss and schist of Donegal lithologically are very unlike, while apparently they are identical with the metamorphosed Ordovicians of the Schuylkill River valley, Pennsylvania (*Mount Alban series,* Hitchcock, or *Hudson series,* Dana). In 1884 and 1885 the late Gerrard A. Kinahan, as previously mentioned (*ante,* p. 276), worked out an unconformability in central Donegal

between the later less altered rocks and the rocks of the older series—gneiss with their associated schists (*Gartan series*). This unconformability in connexion with those previously found by Griffith to the north-east, in the Glen valley, and to the south-east, between the rocks of the Slieve Gallion district and those to the northward, combined with M'Henry's discovery of Arenig fossils in the "Gartan series," ought to make the geology of at least Ulster quite plain;—the gneiss and associated "Gartan series" being the equivalents of the *Arenig* and *Cambrian*, while the later metamorphic rocks represent the upper part of the *Ordovician* and more or less of the *Llandovery* (*May Hill sandstone or Passage beds*), the lower portion of the Ordovician (*Llandeilo*) being absent in this province.]

The Cambrians or Arenig of Antrim (?), Donegal, Leitrim (?), Sligo (?), Mayo, and Galway are all more or less altered into schist, gneiss, or even granite; and in these, at the present time, no fossils are recorded, except the recent finds in the rocks of the Co. Donegal. In Co. Galway they are found in the Ordovicians, but not in the underlying Arenigs or Cambrians (?). In places, especially in the Co. Donegal, some of the gneiss and quartzyte are very little changed, but in general all the arenaceous rocks are more allied to quartzyte or quartz rock (*greisen*) than to sandstone or grits.

In Dublin, Wicklow, and Wexford, some of the Cambrians are metamorphosed, especially in the latter county, where, to the south-east, they are changed into gneiss and granite; but in places in them are quartzyte and quartz rock (*greisen*), and in the unaltered portion grits and sandstones.

ORDOVICIAN and LLANDOVERY.

[In the Table of Geological Strata, "Metal Mining" (*ante* p. 204), the *Passage beds* between the Ordovicians and Silurians are called "May Hill Sandstones," or "Llandovery." In this Paper the latter name will be used. In Clare, Tipperary, and south-east Galway, the Llandoveries are more nearly allied to the Ordovicians; but in the Dingle promontory, Co. Kerry, they are joined on below the Silurians.]

Many of these rocks are metamorphosed, as more fully mentioned in the descriptions of the counties. Some of the grits and sandstones are capable of dressing well; but only a few of them are now in request for cut-work purposes, as the younger and softer stones are preferred. They were, however, used in many of the early structures, and proved good and durable stones. They were also used in many of the Pre-historic megalithic structures, as they were capable of being raised in massive slabs.

SILURIAN and DEVONIAN.

[Except in south-west Ireland (Cork and Kerry), these rocks seem to be rather mixed up. The Devonian proper are the equivalents of the "Lower Old Red Sandstone," or *Passage beds* between the Silurian and Carboniferous; but in many places, either stratigraphically or lithologically, it is hard to determine whether the rocks should be called Devonian or Silurian, as the lower beds of the Silurian (*Smerwick beds*), the upper beds of the Silurian (*Dingle beds*), and the Devonian, are all, lithologically, more or less identical. Their exact age, therefore, cannot be positively stated, except in such places as Cork and Kerry, where good continuous sections across the strata are exposed (see *Kerry*, p. 567). The lower rocks in the Silurian are usually reddish, or purplish, and over these are light-coloured fossiliferous rocks (shades of grey, green, and blue); but still higher up on these, in all the Irish tracts, there are rocks more or less similar to those below. Hereafter, in these descriptions, the reddish rocks will be called of the "Old Red Sandstone type," and the lighter-coloured rocks "Typical Silurians."]

In some of the new maps there has been a curious dividing up of the Silurians: this is especially conspicuous at Lisbellaw, Co Fermanagh. This is an interesting locality, as the condition under which the "Lisbellaw Conglomerate" accumulated, must have been very identical with what is now going on at the Chesil Bank. In Lyme Bay the "flow-tide" current runs from the westward; and this current, accelerated by the wind-waves, carries the Chesil Beach along with it, to be accumulated in the bight behind, or westward of, Portland Bill, which acts as a groyne. Chesil Bank, or beach, becomes coarser and larger as it is followed east, till it forms a massive heap of shingle to the west of the Bill; but eastward of the Bill, in Weymouth Bay, there are finer accumulations. In Silurian times similar forces were at work in the neighbourhood of Lisbellaw. Running north-eastward from Lisbellaw was a coast-line, while west of the village there was a spit, or "Bill," of Ordovician, and west of the latter a bay. Along the north-east and south-west shore the "flow-tide" current ran south-west to Lisbellaw, the shore accumulations increasing in magnitude and coarseness from the north-east towards the south-west. Thus we find at the north of Lough Eyes their conglomerates lying unconformably on the Ordovician; to the south-west is the massive "Lisbellaw Conglomerate" accumulated against the Ordovician spit, that acted as a groyne; while in the bay, west of the latter, sandstones and shales accumulate. Thus, there is a parallel in both places, as along the shore-lines the beach gets coarser and

larger down the current, till it comes to the groyne, when it accumulates, while westward of the groyne the accumulations are fine and small. On the map, for no perceptible reason, the "Lisbellaw Conglomerate" is made to belong to one geological group, and the conglomerates of Lough Eyes to another. (*Antea*, p. 504.)

In these groups there are in places sandstone: these, from the ancient structures in which they were used, are proved to be durable, and capable of producing good work; now, however, they are not much sought after, except for local purposes, partly on account of their hardness, but more generally on account of limestone being found in their vicinity—the latter rock, in such localities, being now more generally preferred for cut-stone purposes. Quite recently, however, in a few localities they seem, in some measure, to be rising in public estimation.

CARBONIFEROUS.

The Carboniferous sea in the Irish area must have been of different depths, besides having in it islands varying greatly in dimensions. The rocks deposited in the greater depths seem, for the most part, to have been arenaceous and argillaceous (*Lower Carboniferous Sandstone and Shale*, or *Yellow Sandstone*—Griffith); but similar rocks were also afterwards deposited as littoral accumulations on different geological horizons, even up into the Coal-measures; therefore rocks of this class are formed not only under all the limestones, but also at different higher levels; they solely indicating different localities near ancient land in the Carboniferous sea. After a time, in some parts the bottom of this sea seems to have grown up, or to have been moved up, causing the water to become shallow, and the conditions more or less like those at the first, so that sandstones and shale (*Calp*), somewhat like those at the original bottom (*Lower Carboniferous Sandstone*), were again deposited.

In Munster, the adjoining portion of Leinster (*King's* and *Queen's Counties*), and in north-western Connaught (*Mayo*), nearly everywhere the Lower Carboniferous Sandstone occurs, margining the older rocks, and separating them from the limestone. This, however, in general, is not the case in the rest of Ireland. In the Co. Wexford, to the north-west of the limestone, are such shore

accumulations, while south-east of the trough there are none, except a few thin subordinate sandstones. West of the Leinster range, coming up from the south, these shore-rocks gradually thin out, and disappear south of Bagnelstown, not to be met further north except in small patches, such as at Newcastle, south-east of Celbridge (*Kildare*), where, we may suppose, there was a cape, alongside which a beach accumulated. In connexion with the Chair of Kildare, and the other small exposures of Ordovicians, that seem to have been islands in the Carboniferous sea, these shore-beds only occur at one side of the older rocks. Margining the large protrusions of Ordovicians in the central plain of Ireland, the Lower Carbonifereus Sandstones are very continuous, while in the west of the Co. Galway, margining the older rocks, they are only found at Oughterard and Cong, in places that must have been bays. In western Mayo they are very continuous; but in the rest of that county, in Sligo and Roscommon, they, in general, only occur to the south or south-east of what was the old land: the exceptions being the tracts north-west of the western end of the Curlew Mountains (*north-east Mayo*), and those north-west of the Ox Mountains (*Co. Sligo*). In the large south-west and north-east bay, between the *Ordovician* land, south and south-west of Lough Neagh, and the *Silurian* land, between Loughs Neagh and Erne, the *Lower Carboniferous Sandstone*, except in the north-east portion, was very continuous; but to the north of Lough Erne the Carboniferous Limestones, like as at Oughterard, were accumulated against an old cliff, sandstones only being deposited to the north-east, in the Termon River valley. In the tracts of Carboniferous to the northward (*Donegal*, *Londonderry*, and *Tyrone*), the shore-beds nearly invariably only occur to the north, as in the tracts at Donegal Bay, and westward of Omagh. At Feeny, however, westward of Dungiven, there is a small tract that seems to have accumulated in a small bight, or bay, where the shore-beds were to the southward; while in Fanad, west of Lough Swilly, is the small tract to which attention has lately been directed by Messrs. Hull and Cruise, in which the conglomeritic accumulations, as pointed out in a paper by Mr. Mahony, occur along the southern shore, and silts occur along the northern.

[In the Lower Carboniferous Sandstones, and also in the subsequent "shore accumulations," there are two distinct types, the lowest beds and those on higher horizons

adjoining the shore-line, respectively, being generally of reddish or purplish colours, and more or less coarse, often conglomerates. But not always so, as sometimes they are fine red shales. Above these, or farther out from the shore, the arenaceous rocks become yellow and grey sandstone, with more or less subordinate grey and bluish shales. This graduation generally takes place upwards, but not always; as in Galway and Mayo, near Oughterard and Castlebar, you can trace, along the strike of the bedding, conglomerates graduating into sandstones, and the latter into pebbly limestones. This also can be seen in various other places, as between Ballyshannon and Pettigoe, Counties Donegal and Fermanagh. Griffith was aware that sandstones of both these colours and textures were the basal beds, or "shore beds," of the Carboniferous limestone; but, to meet the nomenclature of the day, he called the dark-coloured rocks "*Old Red Sandstone*," and for the light-coloured he introduced the term "*Yellow Sandstone*." Jukes, however, adopted a different course, as he included both together in his *Upper Old Red Sandstone*.

Of late years this merely lithological distinction has again, in places, been introduced and given an unnatural value; so that we find on the new maps little spots called "basins of Old Red Sandstone," solely because the rocks are of dark colour and coarser texture, while in other places exactly similar rocks are given their natural place: that is, they are grouped as the basal or shore beds of the *Lower Limestone*. In Western Mayo the rocks are placed in their true position; but this has not been done in Eastern Mayo, although, as pointed out by Symes, the classification into two distinct formations is "chiefly lithological" (*Geological Survey Memoirs, sheets* 41, 53, *and* 64, *page* 14, *and footnote by Dr. Hull*). From the description of the rocks of Western Mayo it will be seen that, similarly as Griffith mapped them, these ought also to be "Old Red Sandstone" in the eastern area: that is, if there is "Old Red" in the east of the county, it must also occur in the west, if the lithological character had been given the same value in both districts (*Geol. Mem., sheets* 39, 40, 51, 52, *and* 62, *page* 16). Griffith, and subsequently Jukes, were gradually bringing Irish geology out from the mists of the past, and it seems regrettable that it should now be plunged back again into the dark ages.]

The fauna of the lower group (*Lower Carboniferous Sandstone or Yellow Sandstone*), although it was unsuited for the clearer and deeper waters in which the associated limestones accumulated, did not die out, but emigrated to the congenial littoral shallow waters, afterwards to again spread out in later times (*Calp*), when the accumulations and conditions were favourable. Thus, we find in the Lower Carboniferous] sandstones and shales, in the Littoral sandstones and shales, and in the Calp accumulations, that the rocks and their fauna are more or less similar. There is, however, in places in the Calp, a marked change in the accumulations, they being more or less calcareous, and even in places good limestone. Yet it is remarkable that in them, as in the shaly limestone of the Rathkeale district, Co. Limerick, the assemblage of the fossils is very similar to that of the Lower Carboniferous sandstone, in both being found many forms which are not to be met with in

the intervening Lower or Fenestella Limestone. It might be said that, as the fauna creeps upwards in the littoral beds from the *Lower Carboniferous Sandstone and Shale* to the *Calp*, it should have crept up by similar means from the latter to the *Coal-measures*. This, indeed, may possibly have happened, if John Kelly's classification of the Slieve Beagh series of rocks (*Counties Fermanagh, Tyrone, and Monaghan*), now favoured by Professor Hull, is correct, as these rocks, according to Baily, from palæontological evidence, ought to be classed with the *Lower Carboniferous Sandstones and Shale.* At the same time, however, a very great change seems to have taken place when the major portions of the Coal-measures were accumulating, as they are not essentially littoral deposits, but must, at least in part, represent land and fresh-water accumulations. Griffith's term, "Yellow Sandstone," seems better, as a general one, than "Lower Carboniferous Sandstone," as it does not express on what horizon the rock accumulated, while it suggests that the accumulations were marginal between the Carboniferous and older rocks; but the latter name seems now to be more generally preferred.

In south-west Munster the Carboniferous rocks are different, they being of the "CORK TYPE" (*Carboniferous Slate and Yellow Sandstone*). These consist, in a great measure, of slates and shales, and they graduate downwards into the Devonian. The arenaceous rocks in them are below the *Yellow Sandstone*, and higher up, on different horizons, are the sandstones called by Jukes *Coomhoola grits.* In a few isolated places the Carboniferous slate graduates upwards into *Coal-measures;* but in the latter the grits and sandstones are of small or no account. Going eastward towards Cork Harbour, the Carboniferous Slate becomes split up and interstratified with limestone; while further eastward it loses its individuality, being replaced by rocks more or less of the "CENTRAL IRELAND TYPES."

In the rest of Munster there are below, and also as littoral accumulations, the *Lower Carboniferous or Yellow Sandstone* (Upper or Carboniferous Old Red), and still higher up the grits and sandstones of the *Coal-measures.* The Calp here (more or less argillaceous) is a middle division in the limestone, but having in places arenaceous calcareous rocks, or, as at Castle Lambert, Co. Galway, an impure coal seam. These, however, as sandstones,

are not of much account, except that in some places they produce good flags. Here it may again be mentioned that, in the limestones of the Calp of the Co. Limerick, there are many *Lower Carboniferous Sandstone and Shale* fossils.

In Leinster and South Connaught the Carboniferous rocks are very similarly circumstanced to those of North Munster, but in North-east Connaught and Ulster there are marked changes. In the south portion of Ulster and adjoining part of Connaught there comes in as a middle group in the limestone, or as independent groups or beds on different horizons, very pure arenaceous rock; they, the *Calp Sandstones*, being quite distinct from the *Yellow Sandstones* below and the *Coal-measures* above. In these Calp sandstones, the " Fermanagh sandstones," and the Calp of the Ulster type, are procured the stones now of most note in the market. As a rule, the sandstones in the Coal-measures are considered too hard, although in Leinster some of them are really good stones; while the Lower Carboniferous stones are often ignored. This, however, may be due to prejudice or some other cause, as near Thurles and Dundrum, Co. Tipperary, there are stones said by the builders who have worked both to be better than any of the "Dungannon stones" (*Calp*).

At the present time the geology of South Tyrone, the extreme north part of Monaghan, and the adjoining portions of Fermanagh seems to be mixed up. In this area, in Slievebeagh, Carnmore, and in the country to the eastward, there are sandstones and shales that Griffith mapped as Calp, because apparently they were identical with the Calp near Dungannon, in Co. Tyrone. John Kelly, however, stated that they belonged to the Coal-measures, and called the highest group "Millstone Grits;" and in the recently published maps of the Geological Survey, John Kelly's classification has been followed, and they have been mapped as Lower Coal-measures, the lower portion being called by Phillips' local English name, *Yoredale beds;* it being here divided into Yoredale sandstone and shales, while the upper sandstones are called *Millstone Grits*.

[It seems very questionable if it is advisable to introduce English local terms into Irish geology, more especially when they are inapplicable. Anyone who has compared the Irish Coal-measures with those of England should be aware that the first can only be compared with the "Culm-measures" of Devonshire, while there is no similitude

between them and those of Yorkshire, where Phillips' name was introduced. What English geologist would attempt to divide up the Devonshire "Culm-measures" into Yoredale beds, Millstone Grits, and Coal-measures? The section of the *Carboniferous rocks* in Fermanagh and Monaghan (?) is different to any elsewhere in Ireland. Beginning below, there is—(1) *Lower Carboniferous Sandstone;* (2) *Shales;* (3) *Dark-blue, thin-bedded Limestone, with Shale partings;* (4) *Amorphous Limestone* (Fenestella Limestone); (5) *Shales and Limestone;* (6) *Sandstone;* (7) *Shales;* (8) *Amorphous Limestone under cherty Limestone;* (9) *Sandstones;* (10) *Shales;* (11) *Sandstones, &c.* The groups 9, 10, and 11 belong to the Lower COAL-MEASURES, and 9 and 10, or Lower Coal-measures, may be called the *Fermanagh series*, after the county in which they are best developed, and not after "Yoredale," where the rocks are different. Group 11 is a portion of the Middle Coal-measures. Groups 1 to 4 are somewhat like the rocks of Munster; but groups 5 to 10 are of different characters and arrangement]

This tract is interesting. If we begin to the eastward, we find sandstones and shales, with small coals, to the north of the TYRONE COAL-FIELD (Dungannon), where undoubtedly they belong to the middle or Calp division of the Limestone. In them, as pointed out by Hardman (*G. S. M.*), there are fossils of Coal-measure types. South-west and westward of Dungannon are small tracts of similar rocks; also farther south-west—north-east, south-east, and south of Aughnacloy, all of which appear on the new maps as Calp sandstone; but immediately after we cross the Blackwater—that is, leave the Aughnacloy area, and go south-west—the apparently similar rocks in the district of Slievebeagh are mapped as Yoredale beds and Millstone Grits. Baily contends that these rocks ought to be mapped as *Lower Carboniferous Sandstones and Shales*, as the fossils are of these types; while Kilroe states it is difficult to see any difference between the rocks of the Slievebeagh district and those of the Calp (*G. S. M.*). In these rocks of this *Fermanagh series* (as it will hereafter be called) and in the acknowledged Calp the sandstones are very similar, the "Dungannon stone" in the Calp and the "Lisnaskea stone" in the Fermanagh series being of one class and equally in repute. In the Calp sandstones north of the *Tyrone Coal-field* and in the Lisnaskea quarries have been found similar large fossil trees, while the assemblage of fossils in the Fermanagh series, according to Baily, is that of the Lower Limestone Sandstone and the Calp, and is not like that of the Coal-measures. But as the section in South-east Fermanagh, between Lisnaskea and Slievebeagh, is identical with that of the known Coal-measures in Belmore and Cuilcagh (West Fermanagh), it is evident that these rocks of the

Slievebeagh district must, at least in part, represent the *Lower Coal-measures*, although they are so different lithologically from those of the Tyrone Coal-field to the eastward.

But it must be remembered, as pointed out in my *Geology of Ireland* (1878), that in the Coal-measures of North Connaught there is a marked change, the lithological characters of the *Lower Measures* being very different to those elsewhere in Ireland; as below, immediately above the *Upper Limestone*, a more or less thick group of sandstones appear, with subordinate argillaceous and calcareous strata; while in the *Middle Measures* there are three coals, one of value. In Tyrone also, but not elsewhere, are found workable coals in the Middle Measures.

In North Ulster there are other peculiarities, as the rocks appear to have accumulated in bays or seas of limited extent; and the different groups of rocks, elsewhere capable of being separated, become mixed up; the red and yellow sandstones, the different types of limestone, and even shales, identical, except in fossils, with those of the Coal-measures, being more or less mixed up. These rocks, which may be called the Ulster Calp type, occur nearly altogether north of a line drawn from Lower Lough Erne along the Silurians of the Fintona district to Lough Neagh, excepting the rocks near Cookstown, Co. Tyrone, which are south of this line, and have some characteristics allied to those of the "Ulster Calp type."

The upper group, or the Coal-measures, has, as *Lower Measures* in East Ulster, some five hundred to seven hundred feet thickness of shale, over which, in the *Middle Measures*, arenaceous rocks predominate, while in the *Upper Measures* there is a mixture of arenaceous and argillaceous rocks, with coal. But in North Connaught, and the adjoining part of Ulster, there are immediately above the upper limestone more or less arenaceous strata, and above these shales, and these combined represent the *Lower Measures*. Above these are the *Middle Measures*, which are for the most part arenaceous, but having in them workable coals. In Eastern Ulster (Tyrone), although the strata of the Coal-measures occur in a very similar arrangement to those of Leinster and Munster fields; yet in the *Middle Measures* there are valuabl coals.

At the present time the Coal-measures Sandstone of Ireland,

except those of the Fermanagh series, are not in repute, although, as displayed by some of the ancient structures, they are capable of good and durable work. This will be hereafter mentioned in connexion with the respective counties.

In the *West Munster Coal-fields* the stones are nearly invariably hard and chippy, and although they can be dressed on the face of the beds, they cannot be worked across, as they chip and fly at the edges. In places they produce excellent flags, but to give good joints, the edges of them generally require to be sawn, as they chip on the face if dressed. These flags, if the edges are sawn and the surface planed, make a beautiful even flooring. In the *East Munster* (Tipperary) and *Leinster Coal-fields* there are some good stones for dressed work, as hereafter mentioned. In the *Tyrone or Ulster Coal-field* some quarries have been worked, but the stones are not in request, as better can be procured in the adjoining calp; while in Monaghan and Fermanagh are the well-known Lisnaskea stones; and in the CONNAUGHT COAL-FIELD there are stones said to be good; but as they are very inaccessible, and far from any market, very little seems to be known about them. Good flags, however, have been sent from this field into the market; at one time extensively.

[The flag trade has peculiar features. About fifty years ago, according to the records left by Lewis, the footpaths of very few towns were flagged; but just at that time it seemed to have become the fashion, and the different towns were looking out for places in which to procure flags. This general demand caused many flag quarries to be opened up, and in some places instituted a large industry. But after the towns were flagged the demand decreased, some of the quarries having been scarcely worked since, while in those places where a trade had been for a time established, it has since died out, on account of asphalt being now more generally used than flags. However, there seems to be a slight reaction in the favour of flagging, as the asphalt in many places seems to be getting into disrepute. In various places in Ireland there are large flag quarries, where hundreds of hands were employed, that now are quite idle. Belgium sends into the market a large quantity of chimney-pieces, made of flag very like that of our Coal-measures; and fifty years ago a large trade in somewhat similar work was carried on at Killaloe, Co. Clare, and other places, the Killaloe chimney-pieces "being in very general request." Now a "Killaloe chimney-piece" is not heard of, the trade having totally died out; while in the Moneypoint flag quarry, on the Lower Shannon, from which the flags came, instead of hundreds of workmen, you will rarely find half a dozen. Very superior work of this class used also to be turned out from quarries near Mountmellick, Queen's County, and other places hereafter mentioned. The Belgians do their work "by the piece." A man is paid so much for the job; and he, his wife, and his children, down to a child that can scarcely walk, are put to do something, at which they work early and late. In Ireland,

however, such things are nearly invariably done by days' work, in limited hours, consequently in one case the work can be done much cheaper than in the other, and the goods sent into the market much cheaper. The Belgian chimney-pieces now in the market are enamelled, which was not the case with the Irish chimney-pieces formerly in the market. It is for a similar reason—"cheap labour"—that the Belgian red marbles have cut out, in the English markets, the "Irish reds," although the latter are superior.]

PERMIAN.

In a few places there are conglomerates and sandstones said to be of this age; but in some places those supposed to be Permian are probably Carboniferous, and in others probably Triassic; they being the upper beds of the first, and the lowest bed of the other.

TRIASSIC.

The sandstones, or *Redfree*, as they are generally called, are free-working stones, and capable of producing fine work. They, however, except in a few places, are not durable, also most of them are liable to discolour; and although the stones may be selected with great care, yet nearly always some will become unsightly, spoiling the general effect; still buildings with dressing and quoins of these sandstones, and walling of limestone, or even basalt, have an effective appearance. Exceptions to these general characters are the stones of North Down, Scrabo, and Dundonald, as from these, especially the latter, stones of good repute are procured. The hard texture of these may possibly be due to the associated igneous rocks.

JURASSIC, CRETACEOUS, EOCENE, AND DRIFT.

In the groups of strata later than the Triassic the few sandstones that occur are of little account for building purposes, they nearly invariably being too frail to be thus used. Some of the drift sandstones are only in course of formation at the present time, sand and gravel being cemented together by water percolating through them, charged with carbonaceous, silicious, or ferriferous matter.

SAND AND GRAVEL.

In a few of the older rock groups there are *sands* that occur as rotten or disintegrated portions of beds of sandstones or other rocks. These, however, are comparatively rare, as the principal places in which the sand and the gravels are found are as portions or beds of the *Drift*, *Alluvium*, and *Diluvium*. Under the latter circumstance they often occur in considerable quantities; in some places younger drifts being made up nearly altogether of them. They have been used in the manufacture of glass, for building purposes, for manure, and many of the gravels for road metal.

The coast sands, that is, those found in the tracts and dunes of Æolian sand, which occupy such long and sometimes wide tracts in places round the coast-line, seem capable of being made much more remunerative than they are at present. If no other use can be found for them they ought to be planted, as has been done in Gascony, and other places on the wild coast of the Bay of Biscay. Their frail nature, and tendency to travel, has given them a bad name; but experience in France proves that they will grow fir timber profitable for turpentine and pitch; while after the woods are established, the shedding of the leaves and the roots of the trees fix the sand so, that portions, if judiciously cleared, can be converted into excellent and remunerative tillage-land. It should, however, be mentioned, that in Ireland, in a few places, by judicious management, they have been made more or less remunerative.

Many of these Æolian sands, especially when Calcareous, ought to be extensively used as manure. Some of them were utilized for this purpose formerly; but of late years nearly all are ignored, as the artificial manures can be more easily procured, although eventually at a much greater cost.

There are other sands, also gravels, valuable as manure; these will be mentioned in their respective counties.

For the ancient bronze castings the mould in general seems to have been cut in sandstone, as many such moulds are found in the old settlements. In modern times they are generally made of sand. As to where the sand used for these moulds in the different foundries was procured we can give very little information.

Adjoining the Arklow Chemical Works a barricade of upright timbers was erected to prevent the mass of Æolian sand, during

east and north-east gales, from drifting and blocking up the quay and entrance to the works. Through the fine joints of the timbers in this barricade a minute silicious sand drifted, and this has been found to be highly valuable for use with the saws of the marble and other stone-cutters, it being sent to Dublin for these purposes. Ireland seems to be remarkably deficient in "sharp-sand" suitable for stone-cutting, most of it being imported. Here, therefore, there appears to be a suggestion as to the introduction of a new industry; for in different places along these Arklow Æolian sands, or on the other accumulations of silicious sand along the south-east coast, similar barricades to that at Arklow might be erected, and the fine sand drifted through them sent into the market to meet the present deficiency.

Glass.—As to the former Glass trade, we have the records of when it was established; but in most cases it is impossible now to find out where the sand came from. In some cases, however, we know that Irish sands were used. As glass beads are common as Irish antiquities, they seem to suggest that in old times our sands, in different places, were used in the manufacture of glass.

In different cases, as will be hereafter seen, the qualifications of a stone is a vexed question; as what one authority approves, another disapproves. Where the opinions are conflicting, the names of the authorities are given. In many cases this disagreement may be more apparent than real, as in most quarries there are different classes of stone—one sent to one market, another to another—so that the opinions expressed, although apparently in reference to one and the same stone, may not be so. Also, in some of the quarries all the good stone, once in good repute, may be now exhausted. Fifty years ago all the builders knew the "Slush stone," Co. Fermanagh; while if you ask the men of the present day their opinion of it, probably they never heard of it, its day having long since passed away, as the good stone in it has now become too expensive to work on account of the "off baring."

Necessarily, in a Paper of this kind, some of the statements may require modification, or other correction; while there may be quarries left out of the lists that ought to have been mentioned. Such omission, however, will, as far as possible, be corrected hereafter in an Appendix.

The descriptions are given in the counties, arranged in alphabetical order, under the different Geological groups, as adopted in the Table of Strata in the Introduction to the Paper on Metal Mining (*ante*, p. 204). The records of the Sands and Gravels are not as full as they ought to be; but on these subjects it is hard to get satisfactory information, as most previous writers have, in a great measure, ignored them, except in general description, from which very few details can be learned.

In the compiling of this Paper, as in the previous one on "Marbles and Limestones," I have necessarily been greatly indebted to Wilkinson's standard work; and of all stones mentioned by him his descriptions are given, except that his arrangement is modified to suit mine. I have also consulted Lewis, and the Memoirs of the Geological Survey, the quotations from the latter being initialed *G. S. M.* But the information from Lewis cannot be specially acknowledged, it being too general, and having afterwards to be verified. I have also received valuable information from the Officers of the Board of Works, through Mr. Commissioner S. U. Roberts; some of the County Surveyors, and various private individuals; whose aid, when possible, has been acknowledged; but in many cases this was impossible, as the same information was received from different sources, or the different information about one place had to be incorporated.

COUNTY HISTORIES.

ANTRIM.

Arenig (?) or Ordovician (?).—To the north-east of the county, principally in the barony of Cary, now better known as the Ballycastle district, is a considerable tract of metamorphic rocks, probably the equivalents of either the Ordovician or Arenig. Among these are some rocks that still in part partake of the nature of grits or quartzyte, but none of them are eminently suitable for cut-stone purposes.

Silurian.—On the east coast, in the neighbourhood of Cushendun, there are massive conglomerates associated in places with sandstones. These rocks seem evidently to be a portion of the littoral or shore beds of the *Ulster and Connaught Silurian Basin*, heaved northward by the faults of the Lough Neagh valley.

In places some of the conglomerates can be raised in blocks very suitable for piers and other rough work, while some of the finer beds can be used for cut-stone purposes. "The fine beds at Cave House were at one time largely quarried, and shipped to Belfast for building purposes" (*G. S. M.*).

Carboniferous.—Near Benmore, or Fairhead, is a small tract of *Ulster-type Calp*, where there were some workable beds of coals, for which reason it is commonly known as the Ballycastle Coal-field (*see Antrim*, "Metal Mining," *ante*, page 264). Here are some stones of great durability; but as some beds are better than others, they should be selected with care and judgment. The best stones are whitish or creamy, finely granular, nearly entirely silicious, but slightly micaceous, and having a few iron spots. Some beds, although otherwise good, are liable to discolour.

Ballyory Quarry.—Three miles from Ballycastle, where there is a railway station. Wilkinson thus describes the stones: "Best stone very fine-grained and friable, almost entirely silicious-grained, slightly micaceous, and with a few iron spots; works easily and well. In selecting the stone, blocks showing iron spots should be rejected." But Mr. Gray says: "Irregular in texture, gritty, and in many beds soft. Carefully-selected stones stand exposure; but as a rule it is not a good stone."

In colour it is pink-white or creamy. Of the latter there are two kinds, one coarse-grained and very strong, admirably suited for bridges, piers, and other strong work. It has been used for many of the bridges in the Co. Antrim, including the viaduct, in places 90 or 100 feet high, over Glendun, in the latter having been used in all the most particular and trying parts. This viaduct has now been a great many years built, and there are not the slightest symptoms of decay in any of the Ballycastle stones used therein. The Ballycastle bridge, after it was carried away, was rebuilt in 1852 with this stone, and the chisel brushings are now nearly quite fresh. Here the durability of the stone has been considerably tested, as during spring-tides they are wet, and

at other times, especially during the heat of summer or in frost, quite dry. These tests the stone has stood well.

The second is a fine stone, taking a beautiful edge, and suitable for the finest work. It can be worked on any surface, where it is equally durable, as it does not require to be laid on its own bed. The spire of Ballycastle Church, built in 1756, is of this stone, and has remained perfect ever since. It was also used for dressing, facing, and other purposes at Doon Hill, Co. Londonderry, built by Lord Bristol, then bishop, in 1783 to 1785, and the cornices and fine work are still quite fresh. In Belfast it contrasts favourably with other sandstones. The spire of the Charitable Institute, built 1774, is of this stone, and also the portico of St. George's Church. The latter was originally in Lord Bristol's palace of Ballyscullion, and was removed to Belfast after the palace was burnt down. These have shown no signs of decay, while English, Scotch, and other stones in the Belfast structures have had to be painted or re-dressed. This stone was also used for the dressings in the Grain Market; and in Coleraine for the inside dressings in the church. It was formerly used largely for Tombstones, but at present only a little.

In Ballymena, the nearest large town, it is not now used, as the Scotch stones are cheaper. The Dungannon stones, Co. Tyrone, are, however, still cheaper, costing 4*s.* a ton, while the Scotch is 10*s.* The spire and dressings of the west church are of the Dungannon stone, while it is also generally used for window-sills and such like. The quarries about Dungannon yield different stones. From Bloomhill come the stones most used and preferred in Ballymena; but in Belfast they prefer the Ranfurly and Carlan stones.

Fair Head.—Red. Works freely; durable; used throughout in the Ballycastle Coastguard Station. (*J. Cockburn.*)

TRIASSIC.—This occurs more or less as a fringe, margining the later rocks to the eastward. It is commonly known as "Red Free." This sandstone works easily and finely, but almost invariably it is very friable and weathers quickly. Some of the hardest stones are quarried in the vicinity of Red Bay and at Bank Head, near Larne. There are also various quarries in the valley of the Lagan.

For Belfast the "Red Free" is usually brought from Scrabo and Dundonald, Co. Down, where the stone is much harder and

better than in the Co. Antrim. The principal sandstones used in Belfast are given under Co. Down.

Cretaceous.—In places, under the White Limestone (*Indurated Chalk*), are sandstones, supposed to represent the English Greensand. These are locally known as *mulatto stones.* They occasionally are firm enough to be used as building stones; but in general, as pointed out by Wilkinson, they are "too friable and loose-grained to be suitable for good work." Du Noyer has stated that, in the Cretaceous rocks of Colin Glen, there are some fine-grained, thin-bedded sandstones, which were used for lithographic purposes.

Flints.—The flints in the White Limestone, as mentioned in the Paper on "Marbles and Limestones" (*ante*, page 413), were, in prehistoric times, largely used for the manufacture of arrowheads and other implements, being exported into the neighbouring counties. In later times they were wrought into gun flints. So late as 1840 there was a large export of flints from the Whiterock quarries, near Dunluce, to supply this trade and the Staffordshire potteries. Since then flints have been exported from Glenarm and other places for the English potteries and that at Belleek, Co. Fermanagh; while the Eglinton Chemical Co. grind up the flints, and from the powder manufacture silicious bricks, that can stand any heat, and are in great request for the lining of steel furnaces.

Agates.—Some of the flints on Rathlin Island are ribanded, and appear capable of producing beautiful "onyx" and "sardonyx," if we may judge from the specimens in the Science and Art Museum, Leinster House, Dublin. As is well known, the old Greeks and Romans, who ranked agates high among their precious stones, invented a method of staining them. This for years remained a secret with the Italians, till an Italian and German, at one and the same time, both agate cutters, got into trouble in Paris, and while in prison together the Italian cummunicated the secret to the German. Since then the great trades in agates at Oberstein in Germany has sprung up, the major portion, if not all, the rough agates being imported from the La Plata River, America, the German quarries falling into disuse after the American cheaper supply came into the market.

As far as we can learn, there seem to be no records of these Rathlin agates in Leinster House as to whether they are the

stones as found *in situ* in the island, or if rough agates that afterwards were stained. In the Ballinascreen Hills, northward of Draperstown, Co. Londonderry, the "chalk conglomerate," the basal bed of the Eocene, is in a great measure made up of broken flints, that were baked by the subsequent overflow of basalt. In all the naturally stained agates I have seen the colours developed are shades of red, they being of the "carnelian" type, as may be seen in the flint fragments *in situ*, and in the flint implements found in the valley of the Lower Bann, Co. Londonderry. Symes states that the agates of this class are common everywhere in the North of Ireland, where the basalt lies direct on the Eocene basal conglomerate, that is the rock due to the breaking up and re-arrangement of the surface of the limestone. He suggests that the staining is due to an iron solution, combined with the baking due to the overflow of hot basalt. The process must be more or less allied to the artificial production of "carnelians;" but as the natural ones are more opaque than the artificial, an iron solution, as suggested by Symes, may be present. At present we are unable to say if the Rathlin "onyx" and "sardonyx," as seen in the Science and Art Museum, Leinster House, Dublin, have been procured *in situ*, or if they were afterwards artifically stained. The stones, however, whether naturally or artificially stained, give such good results, that they ought to be worth looking after; not, however, for a trade in the island in cutting and polishing, for labour is so cheap in Germany that it would be impossible to compete therewith; but the raw material might be exported to Germany, as it is at the present time from the River La Plata.

[In the "GEOLOGY OF INDIA," Pt. iii., pp. 506, &c., Ball gives an interesting and exhaustive account of agates, and how the colours are produced. Many of the raw Indian agates are identical with those from Antrim, while their origins seem to be very similar, both being baked by overflow of basalt. Besides being used for ornamental purposes, they are largely manufactured into burnishers.]

SAND AND GRAVEL.—As a subordinate adjunct of the flows of Eocene basalt, Lewis records a rough tripoli found at Agnew Hill.

In various places in connexion with the Drift, the alluvium and the diluvium, are sands and gravel. In the drift near Ballycastle

there are valuable sands, due to the weathering of the sandstones of the "Ballycastle Coal-field" (*Calp*), mentioned under Glass hereafter. Red sand suitable for foundry purposes is procured in the valley of the Lagan, and exported from Belfast.

In the valley of the Bann is a deposit of *Diatomyte*, or "Diatomaceous clay." This, although properly a sand, is so fine that it has come to be regarded as a "clay," and the notice of it in this and other counties will hereafter be given in a subsequent paper on "Slates and Clays."

For mortar, excellent *river-sand* is procured from Lough Neagh, near Antrim. Near Lisburn and Ballymoney there is *pit-sand;* but as the latter is mixed with clay bands, it has to be carefully raised. At Hollywood there is good sand; at Ballycastle, as already mentioned, there is also good sand; and at Larne there is *sea-sand* on the beach.

In some places on the coast-line there are *Æolian sands*, that are carted inland, to be used as manure, especially on peaty soil. At Red Bay the Æolian sands bring large rents, they being rented and cultivated by the inland farmers for potatoes, to change the character of the seed, a worn-out stock being renovated after it has been grown in these sands.

Glass.—In the neighbourhood of Ballycastle there is an excellent sand, due to the weathering and washing of the Carboniferous sandstone. This seems to have induced the manufacture of glass at a very early period, possibly in prehistoric times (see *ante*, page 265). Of late the glass trade was for the most part an export of bottles to Scotland. It declined as the native coal increased in price, and finally died out when the glass-house was destroyed by lightning in 1850, or thereabouts.

ARMAGH.

A considerable portion of the county is occupied by Ordovicians; but none of these sandstones, or grits, seem to be favourably received as a building stone.

To the north of the county, in the Blackwater Valley, are Carboniferous sandstones. Some of these, of reddish colours, were said to be of Permian age; but the fossils in them suggest

that this cannot be correct. Some of these sandstones will dress fairly well, but they are not in general request.

Grange. North-north-east of Armagh.—A free-working, fine sandstone, considered to be inferior to the "Dungannon stones," Co. Tyrone, and those of Lisnaskea, Co. Fermanagh. It was used during the restoration of the Armagh Cathedral in 1835; but for the dressed work foreign stones were used, as presently mentioned.

At Armagh there are conglomerates that are said to be Permians. Possibly they may be of that age, that is, the "Passage rocks," from the Carboniferous to the Trias; but it seems more probable that they are the basal beds of the latter. They lie nearly horizontal, as do also the Carboniferous rocks below, and the Trias rocks above, so that their exact age is hard to determine. These formerly were rather extensively used for ordinary building purposes, and some beds for flagging in Armagh.

TRIASSIC.—Sandstones, or "Red Free," occurs to the North of the county, in the valley of the Blackwater, and at Armagh, and seem formerly to have been utilised; but of late they are not of repute. Between 1840 and 1845, when repairing the Cathedral at Armagh, "English reds" were used for the carved head, while about the same time Scotch stones were imported for Lord Lurgan's new house.

In the vicinity of Armagh, near Redbarn, at the bottom of the red beds, either in the Trias or the so-called Permian, is a Calcareous, hard, red breccia that has been used for flagging in Armagh.

SAND AND GRAVEL occur in the drift alluvium and diluvium. Good sharp sands for building purposes are found on the shores of Lough Neagh, near Lurgan, while good *river-sand* occurs about two miles from Armagh.

CARLOW.

The only sandstones and grits belong to the CARBONIFEROUS. They occur in the Lower Coal-measures that extend from Kilkenny and Queen's County into the western portion of the county. Although not now in request, being only used for local building purposes, they are capable of fine and durable work, as may be seen in the exquisitely carved and beautiful doorway of the ancient church in Killeshin Glen. The principal quarry in them is

at *Killeshin*, about two and a-half miles from Carlow, on the road to Castlecomer. The stone occurs in nearly horizontal beds, from 10 to 24 inches in thickness, of a brownish-grey colour, silicious, naturally jointed, and easily raised. From the same strata are procured the so-called "Carlow flags." The principal quarries for these flags are, however, in the Co. Kilkenny, as is afterwards mentioned.

Sand and Gravel.—Sand is found in the alluvium and diluvium, while the upper drift (*Esker drift*) above the boulder clay or glacial drift is nearly altogether gravels and sands. These, in places, are cemented into a conglomerate bed, having associated with them beds of brick clay, to be subsequently mentioned in a Paper on Slates and Clays. Good *pit-sand* can be procured in all the pits, which are numerous in the valley of the Barrow, but perhaps more in the Queen's County (west of the river) than in Carlow.

There is a large extent of good *pit-sand* and gravel at Carlow town, about the railway station, and along the roads running out at that side, where they form the lower stratum of the alluvial soil for a considerable distance.

CAVAN.

The sandstones belong to the Ordovician and the Carboniferous.

Ordovician.—These rocks, although of considerable extent, contain few rocks eminently suitable for cut-stone purposes. Some, indeed, work fairly well; but as good limestone or sandstone of a later age are conveniently situated, they are not looked after.

Scrably. North of Lough Gowna; eight miles from Granard.—Brownish, ferriferous, slightly calcareous; works fairly, but is liable to lose its colour.

Carboniferous (*Lower Carboniferous, or Yellow Sandstone*).—In this group, in the neighbourhood of Cavan, there are some easily-worked stones of a yellowish-grey colour, that have been extensively used in the town.

Latt and Ballyconnell (Cavan).—Yellowish-grey, silicious, durable; works freely. Used in the Cullen College, built 1871.

To the north-west of the county, in the Coal-measure of the Cuilcagh and Benbrack Hills, there are said to be some beds of good stones. These, however, have been rarely worked, and, for the most part, are unknown on account of their backward situation, and the difficulty and expense of bringing them into the market, railway charges being so high. They were, however, once largely wrought into millstones, and next to those from Drumdowney, in Kilkenny, were highly esteemed.

SAND AND GRAVEL.—Usually these are scarce in the county, especially near the capital town, as for building purposes sand has to be procured from a considerable distance. At Bailieborough there is a red *pit-sand*, but not very good.

CLARE.

ORDOVICIANS occur in the mountain groups of Slieve Aughta and Slieve Bernagh. In these are grits and sandstones, but not of much account, except for rough work. There is also a green rock, full of little round bits of quartz, from the size of shot to that of peas, locally called "Porphyry." It is a hard massive stone, good for heavy work, but rises in unsightly blocks.

CARBONIFEROUS.—Margining the Ordovicians, and in a small outlying exposure between Newmarket and Bunratty, are *Lower Carboniferous Sandstones* (*Upper Old Red*). The stones vary much in colour, from nearly white to yellow, reddish-yellow, and red or purplish. Good stone can be got in many places; but there are so many good and large surface-blocks, that only a few quarries have been opened. The stones in the hills, about ten miles from Scariff, have very silicious grains in a felspathic cement; they work rather easily, but wear the tools rapidly.

Ballyheigue. Near Scariff.—Yellowish, gritty, with little cement; ferruginous spots; not difficult to work. In 1842, and following years, this stone was extensively used in the works for the improvement of the Shannon at Killaloe, and subsequently was used for the Workhouse, Scariff; but in Scariff it is not much used, as they prefer the stones procured in the hills, about ten or twelve miles distance.

A vein of excellent stone, equal to the Tyrone stone, is said to

exist near Mount Shannon, at the bounds of the Co. Galway and this county.

As pointed out by Wilkinson, the stonework of the ancient Crypt and Cathedral at Killaloe attest the durability and quality of the sandstones of that neighbourhood.

To the west of the county, in the *Coal-measures*, the sandstones and grits are usually thin-bedded, brownish, and bluish-greys, close-grained, and compact. They are very good for general building purposes, being very durable, and having flat beds, make very strong, good work; otherwise, they are not much used, being expensive to quarry, on account of the great head (overbaring) of drift. They are also difficult to dress, and for cut-stone purposes limestone is generally used in the district.

Ennistimon.—In beds or layers, from 2 to 8, or 10 inches thick. Dark-grey; close and compact; very silicious. Makes good walling. Very difficult to work.

Crag. One mile from Kilrush.—Flags like those at Money Point.

Money Point (on the Shannon).—Flags somewhat like the Carlow flags, but much darker; rough on the surface from tracks of marine worms and other animals. They have been extensively quarried, and exported to different places along the coast of the south-west counties. Formerly they were extensively manufactured into chimney-pieces, at the Marble Works, Killaloe, where there was machinery for cutting them and planing their surfaces. At one time the Killaloe chimney-pieces were well known in the market, and the Works employed a large staff of men, women, and children. Some thirty years ago, however, this trade seems to have died out, and now the "Killaloe Marble Works" exist only in name.

[The history of the Killaloe Marble Works I have not been able to unravel. Killaloe is most favourably situated, having the command of the greatest water-power in Ireland, and ought to be one of the great centres of industry; but for some reasons all this great water-power is allowed to remain idle. Prior to 1850, the Killaloe Works were a great source of employment, not only in the town, but in the flag quarries on the Lower Shannon, and in various marble quarries, principally in Counties Tipperary and Limerick. All of these quarries seem to have failed when the Killaloe Works ceased.]

Sand and Gravel.—Very superior crystalline sand is found on

the shores of Loughs Graney and Coutra. The former were extensively used for the manufacture of scythe boards, the sands being carried for that purpose into the neighbouring counties, as boards made from them were considered far superior to those made from English sands. This sand is the detritus from the Lower Carboniferous sandstone, in which there are beds that were formerly wrought by hand into scythe stones. These were carried by hawkers, and sold to the traders in Ennis, Limerick, Nenagh, &c., or at the different markets and fairs in the neighbouring portions of Connaught, Munster, and Leinster. Before the "bad times" in 1848 and subsequent years, very few mowers along the Shannon and its tributaries used any but "Clare stones" and "Clare boards;" but during that time the making of them ceased, and English and Scotch stones had to be used. A few of the makers who survived the famine attempted to revive the trade, and in 1860 there were a few families in Glenomera and Glendree, near Feakle, working at them. The foreign stones, however, held their own, as they could be sold much cheaper; also they suited the scythes then in the market, as those imported are much softer than those previously made in the country, the former wearing out much quicker than the latter. Fifty years ago a mower on the Callow, along the Shannon, would have a scythe to last him two or three seasons; now the imported scythes never last more than one. The cheap scythes retard the work considerably, as the mowers have to stop so often to whet their scythes.

[As pointed out in the Paper on "Metal Mining" (*ante*, page 306), the Irish iron was much superior to that now in use. There are not now, as far as I can learn, any authentic records as to the quality of the steel, except the traditions of certain smiths who could make a scythe that would "cut wool floating on water," or a scythe that had not to be whetted for an entire day. Such legends are still to be heard in the neighbourhood of the Shannon and elsewhere.]

In the barony of Burren sand and gravel are scarce, being nowhere in abundance. In the neighbourhood of Ennis there is good *pit-sand*; three miles from Scariff there is good *river-sand*; while at Lahinch and Kilrush there is good *sea-sand*.

In places along the coast-line there are duns or accumulations of *Æolian sand*, and in the estuary of the Shannon *manure or shell sand*, formerly extensively utilized.

CORK.

In this county sandstones and grits are the principal rocks, they being of *Silurian*, *Devonian*, and *Carboniferous* ages. (See note on *Old Red Sandstone*, under Kerry, page 568.)

Silurian and Devonian.—The rocks of the hill country to the north and west of the area nearly all belong to one of these divisions, Carboniferous rocks only being found in portions of the valley. The Silurians (*Glengariff grits*) and Devonians (*Lower Old Red Sandstones*) are locally called "brown stone" and "red stone," while the Carboniferous sandstones (*Yellow sandstones* and *Coomhoola grits*) are known as "grey stone."

In numerous places in the Silurian and Devonian excellent and durable stones for tool-work could be procured, as is exhibited in the various ancient buildings, Limestone, however, is now generally used for dressings and other cut-stone purposes. This, in a great measure, seems to be due to the architects and workmen, who have learned and live in the cities where limestone is used, objecting now to use the sandstone; the workmen especially, as sandstones are much harder on their tools than limestones. Limestone, however, in early times, in places superseded the sandstone, as at Cloyne, where the sandstone in the Round Tower was procured between its site and the shore; while the other ancient structures, but more recently built, are of limestone brought from a distance.

The Round Tower of Cloyne, just mentioned, displays the excellent qualities and durability of the stone of the neighbourhood. It is of a light, brownish-coloured sandstone, the work being good, especially round the doorway. Of the work Wilkinson states that the stones are notched one into the other in a peculiar manner; also that their state of preservation shows the durability and sound quality of the material.

From the list given (page 545) and descriptions, for which I am indebted to Mr. Williams of the Board of Works, it would appear that some of the South-west Cork sandstones are well worthy of more attention than they now receive.

Sherkin Island, off Baltimore Harbour.—The stone, when first raised, is greyish; then it becomes tinged with green, probably

due to minute particles of grey copper. It afterwards loses the greenish tinge, but never returns to its primitive colour. It has been extensively used in Skibbereen, where it displays good work, especially in the Roman Catholic church; while its durability is tested in the older buildings. This vein of stone is of considerable extent, being found to the westward in Clear Island, and eastward on the main to the south and south-east of Baltimore Harbour.

Horse Island.—A loose, friable, brown freestone, which has been extensively quarried.

Drumcona, six miles from Skibbereen.—Greenish; hard; semi-vitreous, with calcareous patches; cuts and dresses well. This is a superior stone to those on Sherkin; but the quarry is very inaccessible.

Glandore.—A good greenish grit, formerly much used. In the ruins of Ballymoney Castle its durability is tested. It was also used in Kilcoleman House, four miles from Bandon.

The quoins and chimney shafts at Aughadown House, in the east division of the barony of West Carbery, are good examples of the stones of the neighbourhood.

Knockarowra and Cloghlucas, near Mallow.—Brownish-grey; slightly argillaceous; suitable for plain work.

Rahan Mountain, four miles from Mallow.—Reddish; ferruginous; fine-grained. A superior stone to those nearer Mallow.

Quarry Mountain, near Mallow.—Reddish; silicious, but slightly calcareous; semi-crystalline.

Mountain between Mallow and Kanturk.—Dark-brown; quartzose; semi-vitreous; hard.

Knightfield, three miles south-east of Banteer Railway Station (commonly known as the "Kanturk Quarry").—Used for the quoins and sills of the Lismore school, six miles from Kanturk.

[The following two localities in the Knockmealdown range may be in the "Yellow Sandstone."]

Killemera, near Glanworth.—A nice sandstone for walling purposes.

Araglin, north-east of Fermoy.—Grit stone; gives well-shaped, superior paving setts.

Two miles south of Fermoy is a very good variegated stone, that cuts and dresses well. It was much used formerly, but after-

wards was in a great measure superseded by limestone. Bishop's Wood, near Fermoy, supplies flags.

Glanmire Road, Cork.—A deep-red, fine-grained stone.

Templegall, or *Whitechurch*, seven miles north-west of Cork.—Good building stones and flags.

Youghal.—A red stone, lighter in colour than the Cork stone. In places there is a conglomerate (trappean), which can be worked into good square blocks, best suited for heavy work, such as bridges, foundation walls, and the like.

CARBONIFEROUS.—In this formation there are sandstones and grits at the base (*Yellow Sandstone*); and higher up in the *Carboniferous Slate*, at different horizons, are the Coomhoola grits. In places many good stones could be procured, but they are not much sought after, being hard and silicious, and quickly wearing the workman's tools.

A good freestone has been worked on *Horse Island;* also near Castletownsend; while, in the Devonshire property, near Bandon, and in the Herrick estate, Innishannon, there are extensive quarries.

In the parish of Brinny, north-east of Bandon, are flags of excellent quality, and in Kilbrogan there is freestone that has been extensively used in Bandon.

A little north of Cork, on the north of the River Lee, the stones in the quarries vary. They are thus described by Wilkinson :—Yellowish-white, close, compact quartzy grains, with felspathic cement, and semi-vitreous; also, green, silicious, close, dense, very compact, but with numerous fissures and bedded portions, the latter causing the stone to fail.

Belleview Quarry. Near Cork.—A good and free-working stone; but the workmen prefer the limestone, to which they are accustomed.

Coolconing. Two and a-half miles north of Kinsale.—Yellowish, brown, and discoloured, silicious, open, small imbedded particles of slate; cuts fairly well.

Shippool. Kinsale.—Yellow-shaded green; semi-granular and quartzose; slightly calcareous.

Ballymartel. Kinsale.—Stones varying; best, yellow, fine-grained, compact, but slightly micaceous.

COAL-MEASURES (*Ballinaquila.* South-west of Dromina).—A quarry of good flags, and quarries of sandstone.

LISTS AND NOTES BY A. S. WILLIAMS, BOARD OF WORKS.

(The localities are in the *Devonian* and *Carboniferous*.)

Baltimore. Hill back of Coast-guard Station.—

Light-grey. National school and residence. Fit for any description of work, and improves on exposure. Has been used in some of the ancient structures near this place. (*Vide* page 542. Stones of Sherkin Island and the mainland to the eastward.)

Ballyalley. Seven miles from Skibbereen.—

Grey grit. Coast-guard Station. This stone, if obtained at a reasonable depth from the surface, is fit almost for any sort of work.

Rosscarbery. The Beamish quarries, west of the town.—

Brownish and yellowish. National Schools, Rosscarbery. Good stone for ordinary work, and, if selected, fit for dressings. Can be raised in very large scantling.

Union Hall.—

Blue argillaceous and slaty grit; very hard. Union Hall and Glebe. Only suitable for rubble and walling.

Ballydonegan. Twelve miles west of Bearhaven.—

Brownish. Coast-guard Station. Stone hardens on exposure. Is fit for any description of work.

Lehanemore. Sixteen miles westward of Bearhaven.—

Grey grit. National Schools. Only used in rubble and walling. Very durable, but not fit for chiselling.

Derrincorrin. Seventeen miles north-westward of Bantry.—

Brown. National Schools. Can be raised in fair-sized blocks. Very durable, but not suitable for dressed or chiselled work.

Dromore. Eight miles westward of Drimoleague.—

Grey grit. National Schools. Suitable for building, or can be raised in large dimensions, suitable for flagging. Can be dressed for quoins, and improves on exposure.

Dunnycove Bay. South of Clonakilty.—

Liver coloured. Ardfield National School, six miles from Clonakilty. Used in walling and rubble, window and door-sills of limestone, which is usual in this neighbourhood.

Timoleague.—

Blueish, flaggy grit. National School, Timoleague. Never used except in dressing for opes and sills. It is easily raised in blocks of large scantling; well suited for piers or other harbour works.

Borleigh. Eight miles from Bandon.—

Grey to brownish sandstone. School and residence, Borleigh. This quarry is historical, the stone having been used in the Timoleague Abbey and other ancient structures.

Rahavoon. Six miles from Bandon.—

Brown. National Schools. Very hard ferriferous vein; only fit for walling.

Millstreet.—

Reddish-yellow. Millstreet Dispensary. A superior building stone, suitable for any description of cut-stone purposes; largely used in church work.

Dromagh.—

Grey grit (Coal-measures ?). Dromagh Glebe. An excellent stone, suitable for all dressed work of small scantling, as it cannot be obtained in large dimensions.

Lismore. Six miles from Kanturk.—

Brown. National School and residence. Hard stone; similar stone very common in the county, and used for walling and rubble, the quoins and sills being procured from the Kanturk and Keelin quarries.

Boherbwe. Eight miles from Kanturk.—

Brown. Dispensary. Stone similar to that at Lismore. Dressings from Kanturk and Keelin quarries.

Inchageela. Quarries in adjoining hills.—

Grey and greenish; flaggy. Inchageela National School and Kilmichael (Tareton) Glebe. Stone hard; with difficulty can be chiselled, but is not fit for dressing.

SAND AND GRAVEL.—Good sand for building purposes is procurable in various places in the different valleys. *Pit sand* occurs in the neighbourhood of Cork and Macroom; while good *river sand* is obtained five miles from Bantry, in the River Snave; in the Lee, three miles from Cork; in various places along the Bandon river and the Blackwater; in the Islin river, near Skibbereen; and in various streams. In numerous places along the coast there is good *sea sand.*

In Bantry and the neighbouring bays there are accumulations of rich *shell sand,* or rather *coralline sand.* Before 1848 there was a large trade in these sands for agricultural purposes, it supporting a large fleet of boats, which dredged the sand, and brought it into Bantry and the other quays, from whence it was carted inland, even over the hills into the Co. Limerick. At the same time there was also a fleet of 35-ton lighters at Youghal, engaged in similar *shell sand* dredging.

Good *pit sand* occurs about a mile from the Blarney Railway Station. It is very generally used in the Co. Cork.

Near Mitchelstown, on the Kingston estate, is excellent *pit sand;* also *river sand* in the River Funcheon.

Near Glanworth, at Dunmahon, very superior *pit sand* occurs on Mr. Dilworth's farm.

At Ballydonegan Bay there is a peculiar sand, due to the crushing of the copper ore. Previous to the Allihies mines being worked, there was no holding-ground for anchors in the bay, and at the mouth of the river there was a gravelly beach. Now there is good holding-ground in the bay and a sandy beach.

For moulding purposes in the foundries the sand is principally procured from Belfast (valley of the Lagan); but some of an inferior quality is got in the neighbourhood of Bishopstown.

Glass.—In Cork there were two large glass-houses for the manufacture of flint-glass, with extensive premises for cutting, engraving, &c., attached to each. One ceased to exist about 1835, and the other before 1840. The sand used seems to have been imported.

DONEGAL.*

For the most part this county is occupied by granitic, gneissose, and schistose rocks. These, from recent researches, are known to belong to two distinct geological groups, the older probably representing rocks equivalent to the Cambrian and the Arenig, while the later represent the Ordovician and perhaps, in part, the Llandovery or May Hill Sandstone. On these older rocks, in places, such as at Ballymastocker Bay, Fanad; Muff, Lough Foyle; along the mearing of the Co. Fermanagh, to the northward of Pettigoe; and in the neighbourhoods of Killybeg, Donegal, and Ballyshannon, there are Carboniferous rocks of greater or less extent, that in Fanad being a mere patch.

Cambrian and Arenig.—The sandstones, grits, and quartz-rocks which occur in the strata supposed to represent these geological groups are now all more or less altered into quartzytes, gneiss, and foliated granite. But some of the quartzytes, especially some of those in the gneiss and foliated granite, are even-bedded, and, when also regularly jointed, they are excellent material for walls and such like; but they will not bear dressing. Many of the altered quartz-rocks are splintery. In places, however, they are massive, and capable of being raised in large blocks; and, under such circumstances, they are more or less suitable for foundations, sea walls, and other heavy work.

Ordovician and Llandovery (?).—The sandstones and quartz-rocks which are supposed to belong to the rocks equivalent to some of these groups are, in a great measure, altered into quartzyte. Some, however, are unaltered or very little altered, as sandstones occur in the Rathmullen district, between the ridge called the Devil's Backbone and Lough Swilly; also in the barony of Raphoe, south of Lough and Glen Swilly. In the Rathmullen district some of these stones dress fairly well, but are liable to discolour. Those in Creeve Mountain, about three miles north-

* See "Notes added in the Press."

west of Rathmullen, have been used for facing in Ramelton. In the valley about a mile south of Creeve Mountain, in the townland of *Oughterlinn*, there are flags; these are good, hard, and silicious, and can be raised of large dimensions—12 feet long by a width of 4 to 6 feet. They have been used in Ramelton; but the place is very inaccessible, the road being very bad. To the north of Rathmullen, in places near Lough Swilly, there are also flags that have been worked for local purposes, especially in the neighbourhood of Long Lough.

In the quartzyte range of Knockalla some of the quartzytes are thin-bedded. They are silicious and hard, and appear as if they could be raised in marketable sizes. These, as yet, have not been opened on; but, if they could be obtained of sufficient sizes, they should be valuable. Up to the present the place has been very inaccessible; but as a pier has been erected in Ballymastockan Bay, at Croaghros, they are now near a port. At the opposite side of Lough Swilly, in Dysertegney, Inishowen, these beds are worked, and produce good flags, that ought to be more utilized than at present.

There are also veins of more or less similar flags in the north of the county, near Crossroad and Dunfanaghy, which are locally used.

[The age of the rocks in the north of Donegal is still undetermined. For some reasons they might be supposed to belong to the later groups, while there are also reasons for supposing they are portions of the older. The geology, however, hereabouts is so complicated, the younger and older strata being folded in sharp inverted curves, that it is quite possible that their exact age will never be satisfactorily known.]

In the barony of Raphoe none of the sandstones have been considered specially suitable for cut-stone purposes, although they are very useful for walls. Those which can be raised in large blocks are good for coarse and heavy work, such as foundations and the like. In a few quarries, however, the stones have been used for dressed work, and they cut fairly well. They, however, are liable to discolour.

Muckish. Three miles from Dunfanaghy.—Quartzyte; open and porous; pure white; semi-crystalline; slightly foliated; very slightly calcareous.

Kinclevin. Nearly a mile from Dunfanaghy.—White quartzyte. with minute divisions of mica.

Errarooey. Near Crossroads.—Yellowish; improves in colour on exposure; silicious; durable; free-working; can be plugged, and hammers well; can be raised in long scantling, and is capable of long bearings; was used in the foundations and coping-stones of Myra Bridge and in the Roman Catholic Church and School-house, Crossroads. The vein extends eastward and westward.

Minnagran. Seven miles from Glenties.—Here the rocks are very much altered, and appear to be more of a gneiss than a quartzyte. The stone is used for dressed work, and in the vicinity it is called "millstone."

At *Carrick*, eight miles northward of Milford, and in places to the westward, there is a reddish, porous quartzyte, that squares fairly well, but will not cut. It is a good building stone, and was largely used in the building of Manorvaughan, or Mulroy House. It keeps its colour, and has a good effect. Locally it is called "red granite."

Killyclug. North of the Letterkenny Waterworks.—Quartzose sandstone; rises in long massive flags; capable of long bearings; good for rough building, such as lintel and posts in farm buildings.

Carboniferous. — In the already mentioned Carboniferous outlier at Ballymastoker Bay, Fanad, there are red conglomerates and sandstones. The first were formerly used, to a small extent, to be wrought into flax-crushers, while the sandstones were used for local purposes.

In the parish of Muff, on the west of Lough Foyle, and to the north of Derry, the rocks consist principally of reddish sandstones and conglomerates, which are used for local purposes.

To the south-east of the county, margining the Co. Fermanagh, that is, northward of Pettigoe, there are in places stones of yellowish-grey shades. At *Lettercrann*, about three miles from Pettigoe, were procured the stones for the stations on the Enniskillen and Bundoran Railway.

In this tract some of the stones are specially suited for flax-crushers and millstones, and forty or fifty years ago many were made.

In the Carboniferous rocks, near Donegal and Ballyshannon, some of the sandstones are of good characters. They are from pale cream-colour and nearly white to reddish and purplish; from very fine to coarse conglomerates. Formerly from this county

there was a large trade in flax-crushers, they being sent on carts into the other portions of Donegal and the neighbouring counties, or shipped from Donegal town to different places along the coast-line.

This trade seems to have been very short-lived. Formerly flax was kiln-dried, the old disused kilns being scattered over the county. In general, the inhabitants cannot tell you what they were for; a few, however, state that in their grandfather's time, some sixty or seventy years ago, before the stone-crushers were invented, all the flax was "beetled," that is, crushed by hand with wooden beetles, and, before doing so, it had to be kiln-dried. The kiln-drying ceased when the crushers came into fashion; and the trade in the latter appears to have died out some ten or fifteen years ago, partly on account of the failure in the flax crops, partly because mills were erected in which the flax was crushed, and partly because, by some of the new modes of obtaining the fibre, the flax does not require to be crushed, but is sold in the unbroken state. The unsold flax-crushers are to be seen everywhere about the town of Donegal; lying in heaps, as if some giants had been playing a game of quoits. They are now put to innumerable uses.

The stones near *Mount Charles* have lately been greatly brought into notice by the Drumkeelan stone being selected for the new Museum and Library, Leinster House, Dublin. Wilkinson, in 1845, stated that the best stone is yellowish-grey, or pale cream-colour, free, felspathic, slightly micaceous, with a silicious ferriferous cement. Of it Mr. Cockburn states:—"It is good and durable, but hard to work; and has been used in the dressing, Town Hall, Sligo; also for quoins and dressing, with other sandstones, in the Killybegs Coast-Guard Station. The Provincial Bank, Ballyshannon, was contracted to have been built with this stone; but, when half up, the supply of good materials seems to have failed, the upper portion being stones from Dungiven, Co. Londonderry" (see *Dungiven*, p. 583).

Altito. Three miles from Donegal.—Dirty yellow. Varying from granular to conglomeritic; very quartzose; semi-crystalline; hard; cement felsphatic. Formerly largely wrought into millstones and flax-crushers; also heavy kerbing-stones. Used for ashlars in Lough Eske Castle.

Drumkeelan. Three miles from Mount Charles Pier.—Creamy, to nearly white; felspathic; slightly micaceous, with slightly calcareous cement. Dresses and cuts well; hardens on exposure. Good strong flags can be obtained here; used in the town of Donegal. Three thousand tons of this stone have lately been shipped by the Messrs. Beckett, to build the Museum and Library for the Science and Art Department, Leinster House, Dublin.

Beauwin.—Used in Killybegs Coast-Guard Station for boat-house and slip. "Coarse and uneven in grain, with large quartz pebbles. There are some beds of a fine texture and a beautiful tint in this place, but there is no regular quarry, the stones being raised off the surface, and where they can be had with least trouble" (J. Cockburn).

Kildoney. Four miles from Ballyshannon.—White, micaceous, silicious grains, with argillaceous silicious cement. This stone dresses and cuts fairly well, and is very durable; used for wall-facing. It is near the sea, and therefore easy of transport, but is not thought as much of as the stones from the Dog's Mountain.

[In this neighbourhood, in the cliff overhanging the sea, is an anthracite, about 7 inches thick. In boring in search of this coal, a sort of emery was struck, 12 feet from the surface.]

Dog's Mountain. Fifteen miles from Ballyshannon.—Light yellow, ferruginous, fine-grained, slightly micaceous; works freely and well. Excellent flagging (was used at the Parish Church, Ballyshannon) can be obtained here.

To the south of Bundoran, in the ridge of Calp sandstone, partly in this, and partly in the adjoining counties, is excellent freestone, which was largely used in the buildings in the town.

Sand and Gravel.—Near the top of the north face of Muckish occurs a very superior silicious sand for glass-making. A little of this at the beginning of the century was shipped to Belfast and Scotland. The place, however, is very inaccessible, and the cost of getting was so great, that it was undersold in the markets by foreign sand.

[£2 a-ton is what it was then sold at. It is coarser-grained than the Belgian sand, but of a better quality. The best Belgian sand at the present time can be delivered in Dublin for 15*s.* a-ton.]

The Muckish sand occurs as a disintegrated bed in quartzyte.

Only the washed and weathered-out crop can be seen and examined. How far it extends into the hill, and its quality when followed in, cannot be known unless a level was driven in on the bed.

[Lewis states there is a similar sand near Lough Salt. This, however, after minute inquiry, I cannot find ; it seems to be unknown.]

Kane points out that, "In several of the bays of Donegal the sand thrown up by the Atlantic storms is of great purity, and fully equal to that in ordinary use amongst glass manufacturers."

Donegal sand was used at the Glass Bottle Works, Ringsend, Dublin, "and found very good;" but owing to the price having risen, the use of it was discontinued.

In some of the streams westward and south-east of Letterkenny, there are sands also due to the disintegration of quartzyte or sandstone *in situ*. Those known are, however, more or less impregnated with iron.

A rather quartzose sand occurs along the railway from Letterkenny to Derry, at Ballyboe and Monclink. The sand from the latter was largely used as ballast on the line.

Pit sand for mortar in general is not very plentiful; it however occurs in Inishowen and near Milford; while there is inferior *pit sand* in the neighbourhood of Dunfanaghy and Falcarrah. A very good greenish *pit sand* occurs a little north-east of Kilmacrennan. A fine sharp sand occurs in small hills in Tullybeg, east of Lough Fern; while about two miles westward of Rathmelton, in the valley of the Leanane, in small esker-like ridges, there is a clayey sand, used in Ramelton. *River sand* from the streams and rivers is, however, in general good; excellent sand for use in Donegal being found in the Dunmurry and Legacorry streams. Other good *river sands* occur near Glenties; above Letterkenny, in the Swilly; in inexhaustible quantity in the Foyle, south of St. Johnstown, used in Derry; in the Finn river, at Lifford; and in various other places. Good *sea sand* is got in places along the coast-line. There are on the west and north coasts very extensive dunes and tracts of *Æolian sand.*

"Close to the village of Muff, fine sharp white *free sand* occurs; used extensively in the neighbourhood and Derry (six miles distant) for scouring steps and such like. In this neighbourhood some of the sandstones are very soft and friable." (*A. M'C. Stewart.*)

DOWN.

Rocks of Ordovician age occupy the major portion of this county; but in these to the southward, among the Mourne Mountains, in the vicinity of Carlingford Lough, are intrudes of granite and other Exotic rocks. Two very small tracts of *Carboniferous* rocks occur, one on the margin of Carlingford Lough, and the other in the vicinity of Castle-espie, at the north end of Strangford Lough; while to the north-west and north, in the valley of the Lagan, northward of Comber, and in the neighbourhood of Newtownards, are *Triassic.* In the valley of the Lagan, over the Trias, are other Mesozoic rocks, and the *Eocene* (?) dolerytes, with their accompanying basal beds.

Ordovician.—The various grits that occur in places in the rocks of this group seem to be only used for local purposes, as in the area there is no quarry of note. In the district the slate rocks are usually used for rubble work; and granite, or Trias sandstone, for groins, dressings, and other cut-stone purposes. At Ballygowan there is a stone used in the National School, which Mr. Grey reports as "very hard, durable, and dark-coloured—nearly black."

Near the "Stone Circle," Millan Bay, and to the south-west of Slievenagriddle, flags of large size can be obtained.

Triassic.—In the quarries along the valley of the Lagan the stone, nearly invariably, is of a deep-red, or brick-colour, and more or less soft and argillaceous. It has been largely used for local purposes, especially for the bridges of the Ulster (now the Great Northern) Railway. There is a considerable quarry at Kilvarlin, near Moira.

To the north of the county, at *Scrabo Hill*, near Newtownards, there is a better class of stone. Here there are different quarries, in which the stone varies greatly in colour and quality, there being shades of grey, yellow, and red; some are argillaceous, others silicious, while they may be friable, or have concealed joints or vests; therefore they have to be selected with great care if good and uniform work is required.

[Blasting is too prevalent in this quarry. Good stones, with a little extra trouble, might be raised by the crowbar and wedge, while, if raised with powder, they are

shaken, and more or less valueless. This remark is not only applicable here, but also in various other sandstone quarries, where the character of the stone is spoilt by the mode of raising the blocks.]

All the stones are free-working, and, if raised with care, and well-selected, are durable. Formerly they were very extensively used in Belfast, but of late years they have been cut out by a very general introduction of Scotch stone.

These quarries also supply good strong flags, from 2·5 to 3 in. thick.

Newtownards is built nearly solely from these quarries; the large Town Hall, as pointed out by Wilkinson, displaying some good work.

The Scrabo stones have been used in Belfast, in the Albert Memorial, St. Enoch, Fortwilliam, Sinclair's, Elmwood, and Donegal-street churches; the Academy, in the offices of Robinson and Hewits, and the warehouse of Robinson and Cleaver, the last two being from the *Glebe Quarry*. They were also used in Stormount Castle and the Model School and Strain Church, Newtownards. Mr. William Gray, M.R.I.A., says of the stone, that it is "very variable in colour and texture, stands fairly well when selected and set on bed, but tilted on edge it will not stand. It works freely, and, as a rule, is of a light-brown colour." And of the "Glebe Quarry":—"It yields a light-coloured stone, of very even texture, and good colour. It is soft, but stands fairly well, and makes a good building stone.

Dundonald. Four miles from Comber:—Red; fine-grained; like the Dumfries stone (*Scotch*), and has been used for it. The quarry does not yield a very large quantity. Has been used in Belfast in the Spencer basin; cottages and villas at Knock; Preston, Smith & Co.'s Warehouse, &c. (*William Gray.*)

The principal Irish sandstones used in Belfast are from the Scrabo and Dundonald quarries, Co. Down; Dungiven, Co. Londonderry; Ballycastle, Co. Antrim; Cookstown, and different quarries near Dungannon, Co. Tyrone; those from Ranfurly, Mullaganagh, Bloomhill, and Carlan being most preferred.

SAND AND GRAVEL.—Good *pit sand* occurs in the valley of the Bann, also at Saul, between three and four miles from Downpatrick, in the neighbourhood of Newtownards, and in other places. There is good *river sand* in various places along the streams and

rivers; while near Kilkeel and Newry the *sea sand* is also good. Red sand suitable for *foundry purposes*, and exported from Belfast to Dublin, Cork, &c., is procured in the valley of the Lagan.

Flint-Glass was formerly largely manufactured in Newry. Although this was in existence in 1840, yet now it seems hard to get information about it.

There was a second manufactory at Ballymacarret, a suburb of Belfast. To this, at the beginning of the century, a few cargoes of Muckish sand—Ards, Co. Donegal—was brought, and found to be very superior; but the expense of getting the sand, and the consequent high price when delivered, drove it out of the market.

DUBLIN.*

There are arenaceous rocks among the *Ordovicians* to the north and south-west of the county, the latter in part being metamorphosed. In the Rathmichael Round Tower, quartz-rock and clay-slate were used; but the masonry is very rude. As beds of limited thickness in the calp division of the *Carboniferous* there are argillaceous sandstones, and there are also sandstones in the Lower Coal-measures.

Carboniferous.—In some of the calp quarries there are argillaceous calcareous sandstones, or arenaceous limestones, capable of being raised in large blocks, and suitable for heavy work, such as foundations, for which they have been extensively used. In some quarries they are thin-bedded, and give good flags. This was specially the case in one set of beds in the old "Windmill Quarry," Rathgar, and some years ago there was an extensive trade in them. As, however, the "overbaring," and consequently the expenses of the quarry, increased, the trade dropped.

In the north division of the county there are patches of Lower Coal-measure rocks. In these there are some grits and sandstones; but although some of them are fair stones, none of them appear to have been used, except for local purposes.

In the city of Dublin sandstone is largely displayed in the public buildings; but none of the cut stone seems to have been obtained in the county, while most of it, especially in the buildings during the last century, and in the beginning of the present, is

* See "Notes added in the Press."

English stone. Portland stone, according to Wilkinson, was used in the following structures:—Old Parliament House, now called the Bank of Ireland; Trinity College, except the Provost's House, for which the stone was procured in the neighbourhood of Liverpool; Royal Exchange; Post Office; Rotundo; King's Inns; Law Courts; Custom House; the dressings at the Castle; the statue, Nelson's Pillar; St. George's Church; St. Thomas's Church; Roman Catholic Cathedral, Marlborough-street. It has stood well, but is much discoloured. For some years past it has fallen off in demand. Its present price in Dublin is two shillings per cubic foot, and one shilling per square foot for working.

From information procured by Mr. R. Clarke we learn the following as to buildings erected since Wilkinson wrote:—

"Subsequently oolite limestone, or Bathstone, was in demand, which may be here mentioned, although somewhat out of place. At present there are four qualities in the market, which are delivered at two shillings and two pence per cubic foot, and dressed at one shilling per square foot. It has been used in the following offices during the last twenty-five years:—Provincial Bank, College-street; Guinness's mansion, Stephen's-green; Standard Life Assurance, Sackville-street; Trinity Chambers, Dame-street; Royal Insurance (?), Dame-street; Crown Life Insurance (?), Dame-street; Commercial Union Assurance, College-green; Law Life Insurance, Sackville-street; and Lancashire Insurance, Sackville-street.

"Caen-stone is used for finer kinds of work than either the Portland or Bath, such as all kinds of inside work.

"Drumfries stone has been used in many of the insurance office buildings.

"Runcorn red was also used in many of the insurance companies' offices as well as in other structures, principally for bands to set off lighter sandstones, or granite. It, however, is not durable, as may be seen in the Augustinian Friary Church, John- and Thomas-streets, where the Runcorn stone has decayed so rapidly, that although only built twelve years, it is now being taken down and replaced by granite.

"Furness Abbey red stone has also been imported.

"Of late red sandstone has been brought from Dundonald, near Comber, Co. Down, and has been largely used in building the new portion of the Great Northern Railway Terminus, Amiens-street.

This stone has a good reputation in Belfast, where it has been largely used."

"Dungannon stone," from Mullaganagh, or the Ranfurly quarry, Co. Tyrone, was used in the new additions to the Royal University, and has held its colour well.

The creamy sandstone from Mount Charles, Co. Donegal, has been used extensively in the new building for the Science and Art Department, Leinster House. This seems to be the first place of note in Dublin where it has been tried.

Sand and Gravel.—In this area, in the ground that is below the two hundred and fifty feet contour line, but more especially below the one hundred feet contour line, there are large accumulations of sand and gravel. In some localities, however, especially those below the lower line, the gravel and sand has extensively been worked out for road and building purposes, large areas being cleared of the accumulations that once existed, so that anyone now mapping the edges of the gravel terraces would draw lines quite different to those of the margins of the original sea-beaches. This is specially the case in the tract between Booterstown and Dublin. As, however, these sands and gravels are so prevalent in the county, good *pit sand* can be procured in numerous places.

The Drift Cliffs of Killiney Bay are for a large part composed of these gravels, and the sands, the washing from the cliffs, have within the last thirty or forty years come into great repute, so much so, that now, almost as fast as the beaches form, they are carted away, to the great detriment of the owners of the adjacent land, as their land, being deprived of its natural protection, is rapidly carried away by the sea. This removal of the sand, and consequent waste of land, has led to various lawsuits.

[Within the last forty years, since the great trade in Killiney gravel has been instituted, the cliffs, from a want of their natural protection, are receding backwards at a rate of at least one foot every year; while, in certain places, the destruction is even much more extensive, exceeding two or even three feet per annum. From careful calculation made on the coast of Wexford, where the natural waste of the drift-cliffs at the present day is greater than elsewhere in Ireland, the average waste is one foot per annum, the excessive waste in two or three other places being three feet per annum, and in one or two as much as four feet and five feet.

These wastes on the coast-line are very interesting, some being evidently due to artificial structures. Thus, the intaking of the north and south slopes in the Slaney lagoon (Wexford Harbour) changed not only the character of the Dodder Bank, at the mouth of the lagoon, but also that of the Lucifer Shoal, six miles off its entrance. And these

changes in the banks have affected the infringement of the currents on the northward coast, so that since these intakes have been made the coast-line of the North Bay, that is between Wexford and Cahore, has been much more rapidly denuded. On the other hand, on the South Bay, or as it is now called on the recent charts, Ballygeary Bay, the erection of the new pier at Ballygeary has quite changed the features of the shores of the bay, by accumulating fulls at the base of the cliffs that previously were rapidly being denuded away. This is especially the case between Ballygeary Pier and Greenore, where there are now "fulls" and apparently permanent beaches in places that ten years ago showed a clean-washed rock surface up to the base of the drift-cliff; these beach accumulations covering up most interesting geological sections, that probably will never be seen again until Ballygeary Pier has disappeared. On the south coast of Wexford the Ballyteigue flats were intaken; here also the change has had great effect, as since the intake the land immediately west of the entrance to the lagoon has been rapidly denuded away; but further westward, in the vicinity of Cullenstown, a foreshore has grown out. If it were necessary, various other cases could be enumerated where there are also changes due to human agencies. In other places changes are taking place from unknown and hard-to-be-explained natural causes, fulls forming or being cut out for no apparent reason. The most remarkable case that has come under my observation is the tidal effect on the middle island of Arran, at the entrance of Galway Bay, where the effects of the tidal currents of late years are perfectly different to those a quarter of a century ago, while there seems no apparent reason for a change.]

Good *pit sand* for building purposes can be obtained at Knockmore, Valley of Diamonds, and Ballywaltrim, Dargle-road, Bray; also at the Moat, Old Connaught. The last is a very superior sand, very clean and sharp (silicious). It is in Lord Plunket's demesne, and is not for sale, but is used by special permission for any very particular stucco plastering rough-cut work. There is no sand equal to it, certainly none to surpass it, in the Co. Dublin. (*T. B. Grierson.*) The *foundry sand* (red) used in Dublin is imported from Liverpool and Belfast, costing, delivered, about 15*s.* per ton. At one time good sand came from Co. Cork, but it does not seem to be used now.

GLASS formerly was largely manufactured; but in 1886 there were only two flint glass and seven glass bottle manufacturers. Through Mr. White of Dublin we learn that at the Ringsend Bottle Co.'s works the common bottle glass is "made by the fusion of the following materials: sand, from the adjoining Sandymount strand; blue clay, from Sutton strand; waste lime, from Bewley and Draper's chemical works; kelp waste; broken red tiles, to give body; rock salt, from Drogheda; refuse manganese; a small quantity of coarse fluor-spar, and oyster shells.

"The materials now used for the finer glass are Antwerp sand,

French chalk, carbonate of soda, oxide of manganese, fluor-spar, and arsenic.

"Ground granite was used formerly for the finer varieties of glass, but was discontinued in consequence of the high temperature required for its fusion. Donegal sand was also used, and was found very good; but, owing to the price having risen, the use of it was discontinued."

FERMANAGH.

To the north-west of the county there is a small tract of metamorphic rocks coming in from those of the Co. Donegal. They are probably the equivalent of the *Arenig*, or perhaps *Cambrian*. East of Lower (North) Lough Erne are *Silurian* of the "Lower Old Red Sandstone" type. The rest of the area is occupied by *Carboniferous rocks*.

The age of the Carboniferous rocks occupying the tract at the south-east of the county, of which the highest summits are Slievebeagh (1255 feet) and Carnmore (1034 feet), is disputed. Griffith considered them "*Calp*," or the middle group in the Limestone; John Kelly, whose opinion is adopted by Dr. Hull, calls them *Coal-measures;* while Baily states the fossils prove them to be *Lower Carboniferous*. As previously stated, we believe that they are *Coal-measures*, and will refer to the lower sandstones as "Fermanagh sandstone." (*See Introduction*, page 524.)

West of Lower Lough Erne, extending S. S. E. from Lough Erne, past Derrygonnell to the Arney river, is another tract of *Calp;* while north-east of Lower Lough Erne, in the Kish district, the rocks are of the "Ulster Calp type," capped to the south-west of Kish by a small tract of "Fermanagh sandstone" (*Lower Coal-measures*).

In the western part of the county are Coal-measures, part of the CONNAUGHT COAL-FIELD, which, as previously mentioned, extends into the province of Ulster.

ORDOVICIAN.—The grits of this group can be used for walling and rough purposes; but, as there are usually better stones in the vicinity, they are only very locally used.

SILURIAN.—The sandstones, which are in the majority in the mass, are generally shades of red, brown, and purple, although

some are yellowish or variegated. In many of them there are argillaceous or shale spots and specks. At Lisbellaw, in connexion with the exposure of Ordovicians, a massive conglomerate abruptly comes in, as if it had been a shingle mass against a head, that acted as a groyne at the end of an ancient strand. The pebbles in it are remarkably hard, and are much used for road metal. The evident circumstances under which the "Lisbellaw conglomerate" accumulated have been given in a Paper on this subject (page 504, *ante*).

These Silurian sandstones are in general too coarse for dressed work, though well adapted for ordinary or coarse work. The finer kind was extensively used in Necarn Castle, near Irvine—or Lowtherstown—the dressing being the Calp sandstone from Lisnaskea. At Castle Archdall, however, in the same neighbourhood, it was used for the quoins and dressing, while the walling is an impure limestone.

In *Ardlogher Quarry*, near Irvinestown, the stone varies, being shades of reddish-grey. It is granular, semi-crystalline, hard, compact, and slightly calcareous. Lower beds mahogany-red to red; argillaceous; laminated and micaceous; works fairly well.

Mullaghfarm. Four miles from Irvinestown.—Brittle and hard to work; used for quoins and common dressing.

Kerlish. Eleven miles from Irvinestown.—Various; generally coarse, conglomeritic, quartz-grain, felspathic cement, and slightly ferriferous; others finer in texture.

Carboniferous.—In the disputed area of Slievebeagh district, here described as *Fermanagh sandstone*, there are some noted quarries. In the neighbourhood of Lisnaskea most of the stones are creamy, yellowish, or slightly greyish, good, free-working, and have been extensively used in Lisnaskea, besides other places in this and the neighbouring counties, such as Irvinestown, Enniskillen, Clones, Monaghan, and Newtownbutler. They do not, however, seem to have gone into the Dublin or other distant markets, although some of them are well worthy of notice. Stones from these quarries were used as quoins and dressing at Crom Castle, and at Necarn, near Irvinestown, for ornamental work.

Tannyby. Near Lisnaskea.—Yellowish-white to reddish-grey; finely silicious-grained; felspathic cement; ferriferous spots; free-

working; many houses in Clones and Lisnaskea are built of this stone; but the quarry seems to be now closed.

Slush Hill. Two miles from Lisnaskea.—Greyish-white and yellowish; silicious-grained; scarcely any cement; ferriferous stains; some beds very friable; easily worked. Some fifty years ago this was the principal sandstone used in Enniskillen, Clones, and Lowtherstown (now Irvinestown). Dartry mansion, Co. Monaghan, and Farnham, Co. Cavan, were built of stone procured here. Now, however, the quarry is not worked, on account of the "overbaring."

Kilturk, or *Mount.* Between two and three miles from Lisnaskea.—A somewhat similar stone; splits into long scantlings. Nearly all the gate-posts and the cut stones for the buildings of the Great Northern Railway westward of Dundalk were procured from this quarry.

Knocknalossett. Seven miles from Lisnaskea.—The stones for Monaghan College and smaller buildings were procured here.

Crocknagowan. Two miles from Lisnaskea.—Stones used in Presbyterian churches, Belturbet and Aughnamullan, Co. Monaghan, Clones Gas Works, and Tempo House; also wrought into tombstones.

Eshbralby. Three miles from Lisnaskea.—Stones used in Inishmore Hall, and for pillars and dressing in Crom Castle, and in the new work, Enniskillen Church. It is also wrought into tombstones, and some of the beds into scythe stones.

Altnabrock, or *Aughnabrock.* Near Lisnaskea.—Clean, fine-grained, and massive; Ulster Banks, Enniskillen, Lisnaskea, and Clones; seems to be much sought after at the present time.

Corraghy, or *Elderwood.* Three miles from Brookborough.—Not in repute for cut-stone purposes.

Carnmore.—Pebbly, silicious sandstone; good; hardens on exposure; easily worked when first raised. This stone formerly was extensively wrought into mill-stones and flax-crushers before these industries declined.

To the north-east of Lough Erne, in the Calp of the "Ulster type" of the Kesh district, there are good stones to be procured in Inishbo (Cow Island) in the north portion of the lake, and in different places north-east of Kesh. According to Mr. Plunkett,

M.R.I.A., the beautifully sculptured cross on Devenish is cut in stone from the latter locality.

[The quarries north and north-east of Kish are in the *Calp* sandstone; while those south-west of Kish are in a small outlier of *Fermanagh sandstone.*]

Good hard silicious stones may be procured in the Derrygonnell Calp area, to the west of Lower Lough Erne—as in the neighbourhood of Church Hill. About Monea they are in general massive, with subordinate flaggy beds. Kerbstones were procured here for the village of Lisbellaw; and in 1800 the town of Enniskillen was paved with setts procured from this neighbourhood (*G. S. M.*).

Some excellent stones have been noted in the COAL-MEASURES to the west of the county. They, however, are far away from any market or town, and are more or less difficult to get at: on which account, and also as good sandstone can be had more conveniently, they are not sought after.

For the following list of quarries, with their distance from Enniskillen, we are indebted to Mr. John Wray, the Borough Engineer:—

Carnmore, 23 miles; parish of Clones; Clones Church and Market-house.

Mount, 15 miles; parish of Galloon; Railway Bridges from Clones to Enniskillen.

Eskbradley, 15 miles; parish of Galloon; Newtownbutler Market-house, Irvinmore Hall.

Aughnabrock, 13 miles; parish of Aughavad; Ulster Bank, Enniskillen.

Stonepark, 14 miles; parish of Kinawley; Derryglin churches.

Leighan, 7 miles; parish of Devenish; Bridges, Lillias river; Kerbs, &c., Enniskillen.

Rossanuremore, 15 miles; parish of Devenish; Bridge and Church, Garrison, Ballyshannon.

Glenashaver, 15 miles; parish of Innismacsaint; Bridge between Derrygonnelly and Garrison.

Killroskagh, 14 miles; parish of Cleenish; Belcoo and Holywell Bridges.

Aghnaglack, 12 miles; parish of Boho; Derrygore House, Enniskillen.

The round tower on Devenish, in Lower Lough Erne, is built of local sandstone, and displays good work, with ornamental mouldings at the base of the cone. There is also the very handsome cross that was exhumed when the tower was repaired about 1878. It displays elaborate and careful work. Since it has been placed in its original site it has considerably suffered from the weather. The stone, as already mentioned, seems to have been procured from the Kesh sandstone to the north-east of the lake.

Sand and Gravel.—There is good *pit sand* near Irvinestown. Good *river sand* can be procured in many of the rivers and streams. That used at Lisnaskea is brought about two or three miles, and what is used in Enniskillen is principally brought by boat from the River Arney, and from near Pettigoe. There is also good *river sand* near Irvinestown.

GALWAY.

The rocks north of Galway Bay are more or less granitic, and Professor Hull has stated that he considers that they are of Laurentian age, this opinion being grounded *solely on their lithological characters*. Unfortunately for this theory, although the rocks in the vicinity of Galway are more altered than elsewhere in the county, they graduate northward and westward into rocks only slightly altered, the fossils in which prove their true ages. The slightly altered rocks to the northward are not included in Professor Hull's *Laurentians*, as in them are found fossils of Ordovician type; those, however, are to the westward. In the latter as yet no fossils have been found, but they have not been properly searched. The fossil evidence in the rocks to the northward proves that these so-called Laurentian rocks are some of the youngest of the metamorphic rocks of the Co. Galway.

[It is evident that the time of the metamorphism which gives their present gneissose characters to the rocks was post-Ordovician; also that the granitic and schistose characters of the rocks are solely due to this metamorphic action, and not to the age of the rocks.]

In West Galway the *Ordovicians* appear to have graduated downwards through the *Arenig* into the *Cambrian*, so that all are now more or less represented. In the more altered portions

(*Ordovician*) there are quartzytes and quartz rock (*gneissen*), while in the less altered portions to the north and to the westward (the latter classed as Laurentians) there are grits.

To the east of the county, in the mountain groups (*Slieve Aughta*), there are also Ordovician rocks; they are not, however, metamorphosed. To the north of the county, from the Atlantic eastward to Loughs Mask and Corrib, is a long tract of *Silurian*, while margining the Slieve Aughta Ordovicians, and in two places on the shores of Lough Corrib—at Oughterard and Cong—are *Carboniferous* sandstones. In the Calp, north-east of Athenry, are calcareo-argillaceous sandstones.

CAMBRIAN (?), ARENIG, AND ORDOVICIAN.—In general the quartzyte and quartz rock are splintery, or break irregularly; in no case are they fit for dressed work. As much better stone can easily be procured, they are rarely used, except for local rough work. Some of the grits in the less altered Ordovicians are fair stones.

SILURIAN.—Good stones from fine to coarse conglomerates. Yellowish-greens, browns, and reds; some easily worked, but not in use, as the localities are backward, and there is no demand. Have only been used in local works. When building Maam bridge, although there was excellent and suitable sandstone in the vicinity, Nimmo brought limestone by water from Cong, Co. Mayo, as he considered it cheaper.

CARBONIFEROUS.—Some of the stones are well suited for cut-stone purposes. Those at the mearing of the county, to the west of Mount Shannon, have been already mentioned (*Co. Clare*, p. 539). To the east of the county are other good stones, locally used in Woodford and Portumna.

A little south of Cappagh, and north of Featherstone Lodge, westward of Woodford, there are stones capable of being ground to a smooth surface, and of making flagging similar to the "Kinnity flags," King's County (p. 576).

Benmore. Two miles from Woodford.—A fine freestone; can be raised in large blocks; suitable for all cut-stone purposes.

Slieve Dart. North of Dunmore, to the north of the county, and partly in the Co. Mayo.—The massive pebbly grits were formerly extensively wrought into millstones. In this hill, not very long ago, was raised very extensively a very thin laminated

smooth flag, locally known as *Dunmore slate*. This, in old times, was used for roofing instead of slate, as will be seen on the old houses in Dunmore, Tuam, and the neighbouring towns in the Co. Mayo. It made a good substantial roof, the weight of the "slates" being suitable to the heavy gales and storms of the county. They were not very unsightly; far less so than the "Stourbridge slate," used in Oxford, England. They, however, required heavy timbering to support them.

In the vicinity of Cong and Oughterard, the tracts of Lower Carboniferous Sandstone are of limited extent, and the sandstone is but little used on account of the excellent limestone in such extensive tracts in those localities.

As loose stone in the islands, and along the shores of Lough Corrib, are some peculiar sandstones. They have not been observed *in situ*, and possibly may be of Silurian age; but in appearance they are more like the Carboniferous rocks. In weathering, excrescences like small gooseberries grow out from some, while others become pockmarked, small concave hollows weathering into them. The latter stones, when weathered, are extremely durable, as can be seen in the chancel arch of the ancient church on Inchnagoill, in Lough Corrib. This arch was restored some years ago by the late Sir B. L. Guinness, Bart., the missing stones being supplied by ashlers cut from similar stones picked up along the shore of the island. The old and new stones were so similar, that now, after a lapse of thirty years, it is hard to say which are the new ones.

It is hard to explain the cause of the growing on the surface of the stone of the "gooseberries." We learn, however, from breaking a block that the "pockmarks" are due to small globular secretions of ferrifero-chloritic matter, that rapidly decay even when exposed to the air. After they are gone, the rest of the stone is very durable.

Sand and Gravel.—These in this county are interesting as well as useful. In the low country, east of Galway Bay, and extending northward into the adjoining counties, are the Eskers that are found more or less continuously across the central plain of Ireland; and where they occur there is a plentiful supply of good sand for building purposes, and also gravel for road metal. Outside the limits of the plain, good *pit sand* can be obtained at

Knocknacarra, near Barna, three miles west of Galway, and in various places in the hills of Connemara, but more especially in the ridges between Kylemore Lake and the sea. In the West Galway hills there are also in places large accumulations of fine sand, locally called "Rabbit Sand," considerable dunes of it occurring in the valley northward of Lough Inagh.

In connexion with many of the lakes there are considerable accumulations of good sand, that at the east end of Kylemore Lough being remarkable for its size, as apparently it is quite recent. At Lough Cooter, in the south of the county, is silicious sand which, as in the neighbouring county of Clare, already mentioned, is famous for its use in the manufacture of scythe-boards.

In the rivers and streams there are excellent sands, those of the Gort river and neighbouring hills (Slieve Aughta) being superior. In the north of the county there is also sand worthy of note in the Erriff river that flows into the Killary, it being of good quality and silicious, being made up of the detritus of the Silurian sandstones from the adjoining highlands. Some of these sands appear to be suitable for glass purposes, although none of them ever seem to have been so utilized.

The *sea sands* are of importance. Some are very suitable for building purposes; while in many places along the seaboard are tracts or dunes of blown sand (*Æolian drift*) of greater or less extent. All of these are valuable as manure for the boggy land, some eminently so, being very calcareous, containing from fifty to seventy-five per cent. of limy matter. In the north Sound, Galway Bay, there are banks of *sea sand* made up of broken pieces of nullipores. Formerly these were extensively utilized; but they have not been as much sought after since the introduction of artificial manure.

[If the bog-land is impregnated with iron, the bog must be first drained before sand is applied, as otherwise the sand does more harm than good. It changes the iron into a soluble carbonate, in which state it is sucked up into the pores of the plants, where it becomes oxidyzed, and kills or deteriorates them.]

KERRY.

The geological groups in which sandstones and grits occur are the *Ordovician*, *Llandovery*, *Silurian*, *Devonian*, and *Drift*.

In the Dingle promontory is a narrow tract of Ordovicians,

called by Jukes and Du Noyer the Anascaul beds. Adjoining these are Silurian, the upper group of which has been called the *Dingle beds*, and the lower group the *Smerwick beds*, the typical Silurians occurring between, as other groups. The Smerwick beds are probably in part the equivalents of the Llandovery or May Hill sandstone. These passage beds between the Ordovicians and Silurians are very similar in aspect and composition to the Devonians, or passage beds (*Dingle beds* and *Glengariff grits*) between the Silurian and Carboniferous, they both belonging to the red types, formerly all included in the "Lower Old Red Sandstone."

[The term Old Red Sandstone once included all red or reddish sandy rocks below the Carboniferous limestone; but by degrees, group after group, as geological knowledge increased, were given special names, and separated from it, till eventually the rocks that remained were those that lay between the Carboniferous limestone and the typical Silurian. Now, however, it is learned that of this remainder the upper portion belongs to the Carboniferous and the lower to the Silurian, while the intermediate passage beds are all that remain to be called either *Lower Old Red Sandstone* or *Devonians*. These beds above the Silurians, also those below them (*Mayhill sandstone* or *Llandovery*), are very similar in aspect and composition; so that in places one has been mistaken for the other. This will be referred to hereafter when describing the rocks the counties Mayo, Roscommon, and Sligo.]

To the south-west of the county are the reddish to greenish type of Silurians that have been called *Glengariff grits*. They in part represent the upper portion of the *Dingle beds*, and in part higher strata. These Glengariff grits graduate upwards into the Devonians, and the latter into the Carboniferous. The Carboniferous rocks in this part of Kerry, that is in the neighbourhood of the bay called Kenmare river, are for the most part of the "West Cork type," they, except near Kenmare, being *Carboniferous slate* and *Coomhoola grits*; but at Kenmare there is a small tract of limestone, and lower limestone shale intervening peculiarly.

In the Dingle promontory margining the Silurians, and lying unconformably on them, are Devonians. These evidently are the equivalents of the Devonians to the north and south of Kenmare river, and in the adjoining portion of Cork; but in the south part of Kerry and in Cork the upper portion of the Glengariff grits is present, while in the Dingle promontory it is absent, thus necessitating the Devonian of the Dingle promontory to lie uncomformably on the Silurian (*Dingle beds*). In the neighbourhood of Kerry Head there is an isolated tract of Devonians. The Devo-

nians of the Kerry Head district and Slieve Mish graduate upwards, through the Lower Carboniferous Sandstone (*Yellow Sandstone*) and Lower Limestone Shale into limestone, while to the east of the county, on the latter, are the Coal-measures.

[The types here are quite different to those in the Kenmare River Valley, except as mentioned, in the vicinity of Kenmare, where the rocks are allied to those of the north-east.]

The sandstones, especially those in the Devonians and Coal-measures, were much more used in old times than at present, as now limestone is generally preferred for cut-stone purposes. The sandstones of the county were, however, principally used in the early Norman architecture; and, from these ancient structures, as exhibited at Ardfert, and in different other ancient ecclesiastical buildings, they seem capable of making good and durable work.

Ordovician.—The grits and sandstones of this age are not of much account at the present time, except for local purposes, as the localities in which they occur are more or less inaccessible. Some of the early structures in the area would suggest that they were capable of being used in good and durable work.

Llandovery or Passage Beds (*Smerwick series*) and Silurian.—In the *Smerwick series* there are many excellent stones of reddish, purplish, and brownish colour, none of which are in demand on account of their isolated and inaccessible position. In the groups next above (*Ferriter Cove* and *Croaghmarhin series*) there are some good beds; but in general they do not appear to be eminently suited for cut-stone purposes; but in the highest group, *Dingle beds*, there are some first-class stones, suitable not only for cut-stone purposes, but for all sorts of heavy work, being capable of being raised in blocks of large dimensions. There is, however, only a small market for them, and they seem to be used nearly solely for local purposes. In the county south of Dingle Bay, in Glen, or the valley adjoining St. Finan's Bay, there is the old structure called after that saint. It is a *cloghaun*, or bee-hive house, built of a fine-grained sandstone of the locality (*Glengariff grits*), without mortar. The stones in the interior of the cell were so neatly joined and put together, that when visited some twenty-five years ago they presented a perfectly smooth and even sur-

face, while the joints were so perfect that it was nearly impossible to insert the blade of a knife between them.

Minnard. Seven miles from Dingle.—Red; very fine; a good colour; very durable; can be raised in large blocks; was used for ashlars and face-work in the Roman Catholic church, Dingle.

Mr. Deane also mentions "a green stone in the Dingle district, used for building purposes."

Ventry. — Yellowish-brown; compact; not heavy; easily worked.

Killarney.—Dark-grey; very silicious; slightly granular.

Ballycarberry (Iveragh).—Purplish-grey; very silicious; slightly micaceous.

Devonian and Carboniferous.—These vary from coarse conglomerates to a fine-grained sandstone or grit. They are often flaggy, and for the most part are reddish, purplish, or yellowish in colour. In general they are durable, and many of them can be raised in blocks of greater or less dimensions, being eminently suitable for rough work, such as piers, bridges, and foundations. They are also capable of producing good, sound, fine work, as exemplified in the ancient structures. Rattoo Round Tower, in the Kerry Head district, appears to have been built from a hard quartzose sandstone, procured in the vicinity; and it displays a cut-stone band round the doorway in good preservation.

In Derryquin Castle, which is principally built of the slate rock of the locality, some of the quoins are, to quote Wilkinson, "of a grey-coloured sandstone resembling pumice-stone, which is soft, and works in any direction, but hardens and becomes very durable on exposure. It is found in a long, narrow vein, adjoining the red sandstone, and occurs near the coast, continuing inland towards the Staigue fort."

Poulawaddra Wood. Three miles from Tralee.—Red; soft; fair-working; Lord Kenmare's castle, Killarney; new Railway Station, and various houses in Tralee.

Tonenane. Three miles from Tralee.—Similar stone to that at Poulawaddra; used in both of the Roman Catholic Churches, Tralee, and other smaller structures.

There are other smaller quarries in Slieve Mish besides those mentioned. Mr. W. H. Deane, County Surveyor, considers the

sandstones to be easier worked than the limestones, but not as durable.

From near Glenbehy were procured the stones for the ashlar work in Aghadoe, Lord Headly's mansion, near Killarney, built some fifty years ago.

COAL-MEASURES.—As already mentioned, there are excellent stones in places in this area, but now in general superseded by the limestone. At *Barleymount* is a quarry, from which the stone was taken for walling-in Aghadoe mansion.

Armagh. North of Milltown.—A quarry in a good brown stone.

In different places in the "Flagstone series," near the base of the Coal-measures, flags have been raised. They are not, however, as well developed as in the Co. Clare, to the north of the Shannon; while there is nearly invariably a considerable "head" of drift, that makes them expensive to quarry; consequently, they are rarely looked after, it being cheaper to use the "Clare flags." At Ballylongford there are fair flags, with black shale partings, at one time quarried for the general markets; while elsewhere are small quarries, that were opened for local purposes.

SAND AND GRAVEL.—*Pit sand* and *gravel* occur near Kenmare, near Tralee, and in the neighbourhood of Killarney; while good *river sand* is procurable in most of the rivers and streams, especially those having their source in Slieve Mish, which carry down a red, sharp, clear sand, used extensively in Tralee.

In several places on the coast of Tralee Bay is a *sea sand*, which is used in Tralee with the stone saws for cutting blocks.

Æolian sand dunes occur in places along the coast. Formerly the calcareous varieties of these sands, as also the *shell sands* dredged up in the bays and the estuary of the Shannon, were highly valued as manure, especially for boggy land. These used to be carried for great distances inland on horseback, even across the hills into the Co. Limerick.

GLASS.—There seems to be no records of glass being manufactured in this county, although some of the fine sands from the Devonian hills seem well suited for the purpose.

KILDARE.

In this county there are not any sandstones that are now used for cut-stone purposes, while the places in which sandstones occur are of very limited extent.

Stones required for dressed or cut purposes are obtained from the limestone quarries at some distances, or from the granite range in Wicklow or Carlow.

In the ORDOVICIANS to the east margin of the county, and in the small protrudes at the Chair of Kildare and Red Hill, there are some subordinate grits and sandstones; while there are CARBONIFEROUS conglomerates and sandstones margining them in places, and coming in from the Co. Dublin, at the Hill of Lyons, to the southward of Celbridge. At Newtown, some miles west of Maynooth, in an outlying patch of COAL-MEASURES, there are also some subordinate beds of grit.

CARBONIFEROUS.—*Red Hill*, a quarry at the northern end.—Red conglomerate; formerly quarried for millstones.

Hill of Allen.—Grits; formerly extensively quarried for millstones.

Ballindolan. North of Edenderry.—Blackish flags; argillaceous and slightly calcareous; used in Edenderry, King's County.

SAND AND GRAVEL.—These are common everywhere in the low country; but some of the sands require to be washed before being used for building. In places there is a sand with a latent calcareous cement: this, when opened in the pits, stands with a perpendicular wall, which does not weather or slip. This sand is valuable as a manure, and formerly was extensively used.

KILKENNY.

To the south-west, coming in from the Co. Tipperary, and to the south-east, coming in from the Counties Wexford and Waterford, are limited tracts of *Ordovicians* (?), in the latter partly altered and associated with granite intrusions; while margining these areas are *Carboniferous Sandstones.* To the north of the county are Coal-measures, part of Slieve-Margy, but now more generally known as the Castlecomer Coal-field.

In this county, as so common elsewhere in Ireland, sandstone formerly was extensively used, but afterwards was superseded by limestone. As pointed out by Wilkinson, the ancient structures testify to the beautiful finished and durable work the stones were capable of producing, as specially exhibited in the exquisite doorway of the church in Killeshin Glen, a little south of the road from Carlow to Castlecomer. According to Wilkinson, the local sandstone was used, and this doorway, as also the doorway of the Round Tower, Timahoe, Queen's County, were "evidently constructed by the same workmen."

The same authority states that the columns, mouldings, and other dressings in Jerpoint Abbey also show what the Carboniferous Sandstones are capable of being put to. Its dressings are of the *Lower Carboniferous Sandstone* from the neighbourhood, and still show the chisel marks after seven hundred years. It is generally believed that the stone was got within a mile of the Abbey, where there are any amount of blocks on the surface.

On the authority of Wyley, it is stated that the sandstone in Jerpoint Abbey was procured in the southern portion of the townland of Ballyhowra. "The stone is very soft, composed of grains of quartz and earthy felspar, with mica to a small amount." "The tradition is that, when the particular beds of stone were reached, they were wrought underground in the form of a tunnel." He considers the stone unfit for outside work. Wyley, in referring to the ruins of an old church half-way between Knocktopher and Newmarket, states that the stone is similar to that used in Jerpoint, but that it may have been procured either in the Knocktopher or Newmarket quarries. (*G. S. M.*)

As mentioned by Mr. Langrish, "Brownstone House," on the left bank of the Nore, between Thomastown and Inistioge, is built of a highly silicious stone of the district, greenish to purplish in colour, hard to cut, but looks very well. Some of the dressings of Inistioge Abbey, founded 1262, are of this stone and of the hard purple conglomerate which shows in Coolnahan Mountain, between Inistioge and Waterford. It is remarkable how shallow the mouldings were in comparison with those cut in the limestone. At Coalcullen, in the Coal-measures, about four miles from Castlecomer, is a stone of a light-brown tint, and easily worked; it was largely used in the restoration of St. Canice's Cathedral,

Kilkenny. A similar stone occurs near Rosenallis, at the foot of Slieve-Bloom. Both are excellent for inside work. The fine-cut stone house of Castletown, near Carrick-on-Suir, built by Archbishop Cox more than one hundred years ago, has the south front of a darkish sandstone, apparently got in the neighbourhood. The Coolnahan conglomerate, above mentioned, rises in large squared blocks, eminently suitable for the coping of quay walls and such like works, as do also the rocks in the glen at Catsrock, near Tory Hill.

Aghavaller Round Tower is built of a brown, slaty-textured grit stone, in irregular courses.

Ordovician.—The grits and sandstones in this group are almost invariably hard and splintery, not being adapted for cut-stone purposes. They are, however, used for rough local work.

Carboniferous.—Very excellent stones occur in various places both in the *Lower Carboniferous Sandstone* and in the *Coal-measures*, as just now mentioned. The hill of *Drumdowney* was formerly famous for its millstones, which were said to be equal to the French. They were sent by water to England, Dublin, Cork, Waterford, and elsewhere. Some of the largest were 5 feet in diameter, and 16 inches in the eye. They were shipped with ease on the Barrow, at the base of the hill. The last stones, wrought about 1876, are in Saul's Mills, near the locality. On the same hill there was also a vein of white stone, fit for all cut-stone purposes of small dimensions.

Lower Carboniferous Sandstone.—*Baunbree.* Near Scagh cross-roads, four miles from Carrick-on-Suir.—Brown, reddish, and yellowish; kind; apparently durable; used in the Roman Catholic church at Tallaghast.

Annefield, or *Tullynacranny*, and *Oldcourt.* Five miles from Carrick-on-Suir.—Yellowish. The stones, except the quoins, which are limestone, for Pilltown New Church were got from Bregaun Hill, near the Annafield plantation.

Drumdoney. Four miles from Waterford.—Red sandstone.

Mr. P. Burtchael, County Surveyor, points out that, although there are now no quarries open, good stone ought to be procurable from the *Lower Carboniferous Sandstones* in the neighbourhood of Thomastown, Jerpoint, Kiltorcan, and Callan, as attested by the ancient ecclesiastical and other structures. At Coolhill, near Kil-

lamery, there are conglomerates suitable for rough work; while at Kilmaganny there is a nice, durable yellow stone, used for cut-stone purposes in the entrance gate, Rossenarra, and in houses in the village.

In the LOWER COAL-MEASURES at *Shankill*, *Kellymount*, and *Conahy*, are procured the flags known as CARLOW FLAGS, on account of their being carted to that town, and sent from thence by water to the different markets. The Shankill flags were considered the best, and ranged in thickness from 4 inches to half an inch. They could be raised as large as 12 or 14 feet square, but in general from 8 to 10 feet long, and 3 to 4 feet wide. At Kellymount the flags were very similar, but of a lighter colour. At Conahy they were considered inferior. Some of them were so thin, that formerly they were used for roofing. Formerly there was a very extensive trade in these flags; but as the "clearing" or "baring" increased on the flag strata, so did the expense of getting them, and they were undersold by other flags. Since then the introduction of asphalt and other artificial footways has greatly lessened the demand for all flags here and elsewhere.

In Conahy, as pointed out by Mr. Burtchael, some of the stones have natural dressed surfaces ("edgers"), which show well as quoins or facings, having the appearance of "nice square cut-stone blocks."

Kiltown. Half a mile from Castlecomer.—Yellow and grey; durable; easily worked; used in the Roman Catholic Church and the wing of the Wandesforde mansion, Castlecomer.

Coolcullen. Five miles from Castlecomer, and nine from Carlow.—Yellowish, kind, and works easily. Used in interior work during the restoration of St. Canice's Cathedral, Kilkenny, and recent work at Freshford Church. Mr. Burtchael points out that the carvings of the ancient doorway of Freshford Church are greatly worn and disintegrated, the stone apparently being like the Coolcullen stone.

Red Sandstone from the vicinity was used in Thomastown Abbey for the capitals of the pillars between the nave and side aisle. On them the carved foliage is much weathered, having been for centuries exposed to the elements, although originally under cover. (*J. G. Robertson.*) Mr. Robertson points out that, in St. Canice's Cathedral, Graigue-na-Managh Abbey, Jerpoint

Abbey (?), and Grenan Castle, in this county, the stone is the same as that so largely used in Christ Church, Dublin, and in the Co. Wexford, in St. Mary's New Ross, and in Bannow Church.

Sand and Gravel.—Good *pit* and *river sand* is very general throughout the county.

According to Mr. Langrish, the best sand in Kilkenny is in the valley of the Nore, at the town. There are good banks elsewhere along the river, but near Thomastown it is mixed with clay. The fine sand for the Kilkenny Marble Works is procured out of the Nore at Three Castles, four Irish miles from the town.

Mr. Burtchael points out that excellent *pit sand* was got at the site of the new glebe-house, Piltown, while the adjoining townland is called "Sandpits." Good sand is also to be obtained near Goresbridge, Inisnag, Thomastown, Castlecomer demesne, and Massford; Kiltormer, near Callan; also Ballincreas, about five miles from Waterford, Ballylusky, one mile, Ballida, two miles, and Knockhouse, three miles from Mullinavat or Kilmacow Railway Station; Ballyhahy, between four and five miles from New Ross; and, in fact, very generally over the county.

In a cave at Serville Lodge, one mile from Kilkenny, on the Callan road, is a very fine sand, but quantity very small.

A sand with a calcareous cement was formerly most extensively used as manure; some of the pits are so extensive, that it has been calculated that they have been worked for at least one thousand years. A sand, considered specially good on hilly ground, was known as *Kilmacow sand*, probably from having first been found or used in that neighbourhood.

Along the tidal portions of the Nore and Suir there is a large tract of what is called *manure sand*, which used to be loaded into barges at low water out of the banks. It contains a large percentage of very fine sand, and was good for heavy soils.

KING'S COUNTY.

The principal localities for arenaceous rocks are the *Ordovicians* and overlying *Carboniferous Sandstones* (Upper Old Red) in the portion of Slieve-Bloom that comes into the south-east of this county. To the south of the county, in the vicinity of Moneygall,

coming in from the Co. Tipperary, are small tracts of similar rocks; while at the western margin there are sandstones on the eastern flank of Knocksheegowna, that may extend into this county.

At the present time none of these stones are in demand for cut-stone purposes, although some of them are eminently suitable, and were used in the ancient structures. In the ecclesiastical settlement at Clonmacnoise, although in the limestone district, and close to an excellent stone of that class, sandstones of a thin, flat-bedded character were used in some of the churches, while the old crosses were wrought out of a fine-grained quartzose sandstone. This is interesting, because, although in places such as Cloyne (Co. Cork), Cashel (Co. Tipperary), and elsewhere, the first structures were built of the local sandstone, in the subsequent ones limestone brought from a distance was used.

CARBONIFEROUS.—*Kinnity.*—In various places more or less near this town, along the north-west flanks of Slieve-Bloom, are small quarries. In some quarries the stones are from 1 to 4 feet thick, and are capable of being easily worked. In other quarries there are flags of a warm yellowish colour, that are excellent for inside work, as they are capable of being finished so finely as to give an even surface, in which the joints are scarcely perceptible. At Gurteen, about nine miles from Roscrea, flags are raised for use in that town; they vary from 1·5 to 3 inches in thickness.

The monument to the Duke of Cumberland in the public square of Birr, or Parsonstown, is of sandstone from the Slieve Bloom district, but whether from bad construction or bad selection of the stone, it does not now give a good appearance.

SAND AND GRAVEL.—The Eskers are numerous in this county, and they supply an unlimited quantity of good sand; also excellent gravel for road metal. The limestone gravel is much used for manure, the best being found in hillocks or at the foot of the hills. This gravel, when burnt in heaps with the paring of the bogs, gives a very rich manure for tillage.

GLASS was formerly extensively manufactured in Birr, or Parsonstown; but when Lewis wrote, in 1837, only the ruins of the glass-house remained.

In 1652 Boate wrote: "Several glass-houses set up in Ireland; none in Dublin or other cities, but all of them in the country;

amongst which the principal was that of Birre, a market town, otherwise called Parsons-town, after one Sir Laurence Parsons. . . . From this place Dublin was furnished with all sorts of window and drinking glasses, and such others as commonly are in use. One part of the materials, viz. the sand, they had out of England; the other, to wit, the ashes, they made in the place, of Ashtree, and used no other. The chiefest difficulty was to get the clay for the pots to melt the materials in; this they had out of the North."

LEITRIM.

At the south-east of the county, margining Longford and Cavan, also in a small exposure near Drumod, are *Ordovicians*, on which reposes the *Lower Carboniferous Sandstone*. A small exposure of *Silurians*, associated with *Lower Carboniferous Sandstone*, occurs near Drumshambo, to the south of Lough Allen: adjoining that lake there is a considerable tract of *Coal-measures*, a portion of the CONNAUGHT COAL-FIELD; while farther northward there is a small outlying patch of similar rocks to the south-west of Lough Melvin. To the west, coming in from the Co. Sligo, is a ridge of metamorphic rocks running north-east to and past Manorhamilton. These rocks have been said to be *Laurentian*, but this is highly improbable (page 517); and for the reasons given when describing the Donegal rocks (page 548), it is probable that they are the equivalents of the *Arenig* or *Cambrian*.

ARENIG (?) OR CAMBRIAN (?).—These rocks consist of green quartzyte and other schists. None of the quartzyte is suited for cut-stone purposes, but it may be used for flags, in rough work, or for road metal.

ORDOVICIAN.—Some of the grits and sandstones belonging to this group seem not to be suited for cut-stone purposes, but locally they are used for rough work.

SILURIAN.—There is only a very small area occupied by these rocks. Good stone can be procured in quantity in some places, but they are not sought after; they are, however, used for local purposes.

CARBONIFEROUS.—In places, but especially in the south of the county, the strata adjoining the older rocks are reddish or purplish in colour, and range from conglomerates to fine sandstone. Some

beds, however, here and elsewhere are lighter in colour, being grey and yellow.

Greenan. Four miles from Mohill, loose masses of sandstone. Between four and five miles from Mohill there are several quarries in whitish and brownish-yellow stone, from which large blocks can be obtained.

Between Dromod and Drumsna, eastward of the road, are different quarries. Whitish, clean, even-grained, quartzose, thick-bedded; irregularly jointed but very large squared stones can be obtained; it dresses well, but is hard to work. This is not much used; but the ashlars, groins, and sills for the Aughamore Roman Catholic church were obtained here, and have produced sharp and durable work.

Cloonmorris. Between Dromod and Newtownforbes.—School-house, rubble and walling; free-working and durable.

Crummy. North-east of Carrick-on-Shannon.—School-house, rubble and walling; very free-working and durable; dressing from Creeve (limestone), Co. Meath.

Curnagan, Parish of Fenagh.—A quarry once well known for its millstones.

Killea. Seven miles from Manorhamilton.—Stones vary in colour and composition. The best is whitish. Fine-grained, silicious, works freely; large blocks can be obtained. Other beds are greyish, slightly argillaceous or micaceous. The quarry was largely worked, but expensive, on account of a heavy bearing, and the upper stones being deteriorated by stains.

Glenfarn. Nine miles from Manorhamilton.—Greyish-white, coarse-grained, silicious, argillo-silicious cement, works well.

In various localities in the Coal-measure hills there are said to be good stones; but they are difficult of access. In places are seams of thin-bedded sandstone suitable for flagging, the natural surface being quite even, and, as they are hard. they are very durable. The flags from the Arigna Hills have been used in Carrick and Mohill, and those from Glenfarn in Manorhamilton.

Sand and Gravel.—In the country to the eastward of the Shannon the *pit sand* in general is good; but westward of that river, for the most part, it is inferior.

Good *river sand* occurs in different places all over the area, but often in limited quantities.

LIMERICK.

To the east of the county, coming in from Tipperary, are *Ordovicians*, overlaid by *Lower Carboniferous Sandstone*. Also to the south of the county, in Slieve-na-Muck and the Galtees, there are *Ordovician* exposures, with *Lower Carboniferous Sandstone* margining. In the plain of Limerick are a few outlying exposures of the latter rocks; while in places in the limestone, as adjuncts of the subordinate inlying traps, are tuffose sandstones.

To the west of the county are *Coal-measures*, a part of the Munster Coal-field, while small outliers of similar rocks are found at Ballybrood and Slieve-na-Muck.

Ordovician.—The grits in this group, as elsewhere, are of little value for cut-stone purposes, although useful locally.

Carboniferous.—These range from a conglomerate to fine sandstone and grit. Although not now much in demand, in places there are superior stones in the *Lower Carboniferous Sandstone.*

Doon.—In this neighbourhood there is specially fine freestone, which at one time was largely shipped to England and other places. The stone is tough, equal to heavy bearings, and can be raised in long scantlings—on which account very suitable for staircases. It was used for the staircases in Clarina and Adare manors.

Glenstal Castle was built of a good whitish stone procured in the neighbourhood of *Morroe.*

St. Oswald's, near Ballingarry, was built with stone procured from *Knockfierna.* Some of the stones in the quarry were easily worked, while other beds were as hard as flint. The house has been built over thirty years, and Captain Wilkinson states the stones seem to have hardened. Stone from near this quarry was used in the Ballingarry Court-house and Church, but not for cut-stone purposes. Mr. Horan, County Surveyor, is of opinion that good stone might be got in this hill if a quarry was opened sufficiently. At present the stone is principally used for rubble work. Near *Kilmeady* there are quarries in silicious grits. In the Slieve-na-Muck range, near Galbally, fair stones might be procured.

At places in the limestone associated with the intruded and bedded igneous rocks are tuffs, that range from massive agglomerates through conglomerates into fine sandstones, often calca-

reous. They are purplish, reddish, and greenish in colour. Where fine-grained they cut easily and well, but are not durable. A green variety, raised out of an adjoining quarry, was extensively used in the building for the new railway station at Limerick.

An agglomerate, that rises in massive, squarish long blocks, was used in the ancient megalithic structures in the neighbourhood of Lough Gur.

In general the COAL-MEASURE grits are very quartzose, and hard to cut or dress, and are not favourably thought of. They have, however, been used in many of the bridges. In places there are excellent flags, similar to those imported from Money Point, Co. Clare. These have, to some extent, been worked in the neighbourhood of Athea, and also at Barna; and the latter were used in Newcastle and Rathkeale. When first raised, they are soft and easily tooled, but afterwards they become very hard. They also occur in the hills near Glin.

SAND AND GRAVEL.—*Pit sand* occurs in the neighbourhood of Limerick, near Kilmallock, near Rathkeale, and in other places. Good *river sand* can be procured from the Shannon above Limerick, in the Deel river, near Newcastle, and in greater or less quantities in the mountain streams. *Shell sand* for manure was formerly procured from the estuary of the Shannon. There are also in places, at about the 240 feet contour line, accumulations of *gravel* suitable for road purposes.

LONDONDERRY.

The sandstones occur in the *Ordovician*, *Llandovery* (?), *Silurian*, *Carboniferous*, *Triassic*, and *Jurassic* groups. To the south of the county, coming in from the Co. Tyrone, are older rocks, probably the equivalents of the *Arenig* or *Cambrian*, that are metamorphosed into gneiss and schists.

ORDOVICIANS AND LLANDOVERY (?).—These are more or less metamorphosed. Some of the less altered sandstones cut fairly well, but are not in request, as better stone can be procured in the Carboniferous. A peculiar, finely-laminated sandstone (*book* or *leaf sandstone*); is very good for walling purposes, and has been extensively used in the neighbourhood of Derry.

Prehen (Derry).—Bluish; of a slaty nature. Does not stand

well, except on the beds, as it is liable to peel and to break at the joints. Used in the Public Offices, Diocesan Seminary, Foyle College, Gwynn's Institution, Roman Catholic Cathedral, &c.

Silurian.—The rocks belonging to this formation are of the "Lower Old Red" type, being reddish and purplish conglomerates and sandstones. They occur to the west and south-west of Draperstown. They are not a desirable stone.

Carboniferous.—There are some first-class stones in these rocks, as hereafter mentioned. They have not, however, been as much in demand as they ought to be, on account of the expense of land carriage, which has allowed them to be cut out of the market by stone imported from Scotland.

These stones range from coarse quartzose conglomerates into fine silicious grits and sandstones of yellowish shades. The latter are easily worked when first quarried, and harden on exposure. They are good for both inside and outside work, and in the old buildings, in which they were very generally used, they exhibit their soundness and durability.

Gort-a-hurk, near Maghera.—Creamy-white, with subordinate greenish beds; very silicious, granular, but little cement; does not work freely. The beautifully and elaborately sculptured doorway of Maghera ancient church, wrought out of this stone, proves its eminent durability. It has been used in Magherafelt.

Fallagloon and *Ranaghan*. Three to four miles north-west of Maghera.—Flags, tombstones, door-steps, sills, and scythe-stones procured in different places; principally worked near the road to the south of Ranaghan.

Carnamoney (Moyala river). Four miles south-westward of Maghera.—Grey and yellowish, silicious; easily worked; used for tombstones, sills, quoins, &c.

Drumard. Near Draperstown.—Bluish. This stone, some years ago, was opened on by the Grahams of York-street, Belfast, and was considered by Mr. A. P. Sharpe, of Dublin, to be a first-class stone. At that time, however, on account of backward situation, and the great expense of getting the stone from the quarry to the market, the enterprise had to be abandoned.

At one time the stones from this part of the county were in considerable demand, and were carted to Ballyronan, on Lough Neagh, where they were shipped to Belfast and other places.

Drumquin.—Yellowish, fine-grained, works freely; when raised, very wet, but dries on exposure; not very durable. This stone was formerly much used in Coleraine and Limavady.

Altmover. West of Dungiven.—Various quarries, varying from white and creamy to reddish greenish-grey; semi-crystalline; argillo-silicious cement; some beds with sand holes. Thin-bedded stones used as flagging in Limavady.

From these and other quarries are procured the stones known as the *Dungiven stone;* and in these different quarries special beds must be better than others, as there is a diversity of opinion as to its quality. From a quarry then known as "Ballyhagan" were procured most of the stones for the Bishop of Derry's (Lord Bristol's) palace at Ballyscullion; but the portico was built of Ballycastle (Co. Antrim) stone (page 532). To the north of Dungiven a quarry has been opened of late years, from which a very superior stone is procured.

Of the stone sent to the Belfast district Mr. Grey states: "This is very excellent stone, of light colour, free from iron, very durable, hammers and tools well; works freely for dressings, sills, and quoins, as well as for rubble work. Has been used in Coleraine Church; in Parish Church, Northern Bank, and Presbyterian Church, Kilrea; Protestant Hall, Belfast; and in the Coastguard Stations at Moville and Rathmullen, for quoins, sills, and dressings."

They have also been used in the Diocesan Seminary, Londonderry; in the Lunatic Asylum (*see Gortnagluck List*, Co. Tyrone, page 608); in St. Columb's Cathedral and the Roman Catholic Parochial Hall. The Provincial Bank, Ballyshannon, Co. Donegal, was to have been faced and dressed with Mount Charles stone; but, when it was half up, the supply seems to have failed, and the cut-stone in the upper portion is from Dungiven. Of the latter *Mr. J. Cockburn* writes: "The stones seem to have been carefully selected, as they are better than most specimens of it to be seen elsewhere in evenness of texture, firmness, uniformity of colour, and freedom from sand holes." They have been used for steps and dressings in different private residences in north-east Donegal.

Glenconway. Eight miles from Limavady.—Yellowish; easily worked; has been used in Limavady, Londonderry, and elsewhere.

Walk Mills. Three miles east and south-east of Limavady.—Brownish and reddish flags, from 3 to 5 inches thick.

Triassic.—Reddish and orange; locally called "Red Free;" very easily worked, but friable, and in general not durable; used locally.

Jurassic.—Thin-bedded sandstones occur as subordinate layers in the band of Lias that margins in places the Cainozoic plateau of Antrim dolomyte. They have been used as flagging, but are soft, and liable to get damp. Formerly they were in great request as scythe stones, a considerable trade in them having been carried on at Magilligan.

Cretaceous and Eocene.—The arenaceous adjuncts of these rocks are the Flints and Agates, the latter occurring principally in the lower *Eocene Conglomerate.* Anciently they were wrought into war implements. They have been previously mentioned in the description of the Co. Antrim (page 534).

Sand and Gravel.—Good *pit sand,* if well selected, can be procured near Coleraine, and Magherafelt, in Bishop's Demesne, Derry, and in the vicinity. Good *river sand* is found near Derry and near Newtownlimavady, being very good along the River Roe.

A fair quality of *sea sand* is procured from the sand-banks at Magilligan.

In Londonderry, in 1820, a glass manufactory was established in the old sugar refinery, Sugar-house-lane, but was closed after a few years. It is not now known where they got their sand.

LONGFORD.

To the north of the county, coming in from Leitrim and Cavan, are *Ordovicians,* which are margined by *Lower Carboniferous Sandstones.* At Granard, however, there are peculiarities, the sandstones being interstratified with the limestones. In the neighbourhood of Longford also, south-west of Ardagh, there are outlying exposures of *Ordovicians* associated with more or less marginal belts of *Carboniferous Sandstone;* while in the *Calp* there are also arenaceous rocks, some of which will be mentioned.

Ordovician.—Here, as elsewhere, the grits and sandstones do not seem to be known, except locally, as none of them appear to be eminently suited for cut-stone purposes.

CARBONIFEROUS.—These rocks, although of small extent, are locally in fair request, notwithstanding that excellent limestone can be easily obtained in the neighbouring counties; and, as mentioned in the previous Paper, the latter class of stone for some years has been principally sought after for cut-stone purposes.

In the Granard district, in general, the stones are whitish-grey or bluish, splintery, and hard to work, and are seldom used, except for walls. There is, however, in some beds, a better class of stone, of a yellowish colour, that works freely.

Ballinacrow. Two miles from Granard.—Yellowish; quartz grains, little cement, micaceous; spotted with iron and calcareous matter.

Dalystown. Four miles from Granard.—Steel-grey; hard, silicious; spotted with calcareous matter.

Ballinamuck. Twelve miles from Granard.—Yellowish; coarsely granular, white grains in an argillo-silicious cement. Here are also to be obtained hard flags of good sizes, that have been used in Longford.

Ardagh.—Greyish-white; open and porous, white grains in a silicio-calcareous cement; ferruginous spots; used in Granard.

Glack. Near Longford.—Over a large tract of country there is a coarse conglomerate. On this conglomerate, in the quarries near Longford, there are sandstones. The latter are yellowish, but becoming white on exposure; coarse, white quartz grains, with yellowish argillo-silicious cement; can be raised in blocks, 6 feet square, and 4 feet thick; used for the buildings in the town, and also wrought into millstones for oat bruising.

Edgeworthstown.—In the Calpy limestone are good flags, very similar in appearance to the Carlow flags.

SANDS AND GRAVELS.—Pit sands procured near Granard, Ballymahon, and Newcastle; elsewhere scarce.

LOUTH.

The major portion of the county is occupied by *Ordovicians*. To the north, at Carlingford, and on the south-east flanks of Slieve-Foye, are small thicknesses of *Carboniferous Sandstone*, and also to the westward, near Ardee.

In the ORDOVICIANS there does not appear to be any quarry of

much note, although in various places there are quarries. When of fair sizes, they are worked for local purposes. Although the stones are hard, some of them dress fairly well.

Carboniferous.—According to Traill, the sandstones near Carlingford are not of much value. (*G. S. M.*)

Kilpatrick. Near Ardee.—Grey, weathering pale-brown, calcareous cement; used for building purposes. Similar rocks are exposed in the bog, two miles N. N. W. of Ardee. (*G. S. M.*)

In the celebrated ecclesiastical ruins of Mellifont and Monasterboice the sandstone dressing used, according to Wilkinson, seems to be Carboniferous Sandstone from the Co. Meath. They and the two large crosses at the latter place are in good preservation, except some badly-selected micaceous stones. In St. John's Gate, Drogheda, the unequal weathering of sandstone and limestone is illustrated. Where the sandstone came from is not known.

[Mr. Sharpe, the well-known Dublin builder, who has carefully traced up the sandstones in some of the ancient buildings, is of the opinion, as already mentioned (*Introduction*, page 510), that the stones at Mellifont are from Doulting, near Glastonbury.]

Sand and Gravel.—Good pit sand occurs near Ardee, and a loamy sand near Dundalk.

River sand is obtained in the Boyne, at Oldbridge, for use in Drogheda.

On the coast are dunes and tracts of Æolian sands, at one time in request as an agent for making the stiff clays of the county friable. They seem now to be very little used; they ought, however, to be valuable fertilizers.

MAYO.

To the south of Clew Bay are metamorphic rocks, with subordinate intrudes of granite. These, to the south and eastward, are overlaid by *Silurian* or *Carboniferous* rocks. North of Clew Bay, occupying the north-west portion of the country, and extending in a narrow tract eastward by Westport and Castlebar across the county into the Co. Sligo, there are also metamorphic rocks and granites, which are overlaid either by *Silurian* or *Carboniferous*.

Of the metamorphic rocks in the east and north-west portions of the county it has been stated that they are of *Laurentian* age;

but, as already pointed out, this is highly improbable, if not impossible. Some of them, undoubtedly, are the equivalents of the *Ordovicians*, and the rest are probably the equivalents of the *Arenig*, or possibly part of the *Cambrian*. North of Balla, to the eastward of Castlebar, is a small outlying mass of *Coal-measures*.

CAMBRIAN, OR ARENIG.—These, as just now mentioned, are, for the most part, metamorphosed into schist, gneiss, or granite. There are, however, some quartzytes and quartz-rock, capable of being raised in large blocks suitable for rough work; but they are seldom used, as other stones, as easily procured, are preferred. They can also be utilized as road metal.

ORDOVICIAN.—These, like the older rocks, are in general metamorphosed; but in places, more especially to the eastward, north of the eastern continuation of the Erriff valley, they are not. In the unaltered portions there are some very massive grits and sandstones that would be valuable for piers, foundations, and such rough massive work, but that they are backward and very inaccessible. There is also a pebbly quartzyte, very suitable for piers; but it does not appear to have been much utilized.

Between Foxford and Swinford are flags of great dimensions. Symes considered that they are due to water freezing in the joints that split off huge plates, some as large as the side of an ordinary cabin. They might be more utilized than they are.

In the north-west of the county (Erris), "between *Benmore* and *Belderg Harbour*, also along the coast of *Broad Haven*, between *Dawish Cellar* and *Blind Harbour*, flaggy quartzytes, in unlimited quantities, light-browns and greys, may be had of any sizes and thicknesses; these are well suited for street flagging, and some beds are easily and cheaply wrought into paving setts. The flags between Dawish Cellar and Blind Harbour could be shipped from either Gubatnockan or Belmullet, and those of Benmore from Belderg. It is proposed to join the latter quarries by a tramway to the harbour and erect a pier there."—(*A. M'Henry.*)

SILURIAN.—These rocks are both of the ordinary and "Old Red Sandstone" types, the latter predominating, and consisting, for the most part, of purplish or reddish conglomerates and sandstones, while the others are principally shades of grey, blue, and green argillaceous rock, in which are grits and sandstones. In one tract, east and south-east of Louisburgh, they are in part meta-

morphosed. Some of the purplish sandstones and conglomeritic rocks can be raised in large blocks, and would be suitable for cut-stone purposes; but, on account of the facilities for procuring excellent limestone, they, in modern times, have been rarely thought of, except near Newport, where some of them have come into favour. In 1845, Wilkinson thus writes of the sandstone then in favour in that town:—"It varies from a conglomerate or coarse-grained sandstone to a very hard red and brown and whitish-coloured grit. This stone is now generally used for all purposes, and is quarried within a mile of the town on the east. The bridge of Newport has the spandril erected with a fine red-coloured grit obtained from the neighbouring mountains."

[In this neighbourhood the Silurians of the "Old Red type" and the Lower Carboniferous Sandstones are rather mixed, being often very similar in colour and texture, so that, except from personal examination in the quarry, one cannot be distinguished from the other. Most, if not all, of the sandstones mentioned by Wilkinson as used in Newport seem to have come from the tract of Silurians a little eastward of the town; but some of them may possibly have been obtained from the Lower Carboniferous Sandstones of the vicinity.]

To the east of the county, between Charlestown and Ballaghaderreen, there is a tract of Silurians. In this the rocks above and below are of the "Old Red Sandstone" type, while between, are green sandstones, with subordinate calcareous and shaly beds that contain Silurian or Llandovery fossils.

[The green sandstones are peculiar, because, except in colour, they are identical in composition with the rocks above and below them. The fossils occur in three horizons. Those below are of Llandovery types; the middle beds contain fossils of Wenlock types, while in the upper beds they are again of Llandovery types. This, therefore, is an example of the places in which fossils typical of English groups cannot be taken as a positive indication of age;—these rocks, as suggested by Griffith, Jukes, and Foot, are probably in part the equivalents of the "Dingle beds" and the "Glengarriff grits" of the counties of Cork and Kerry: that is, the upper beds of the Silurian closely allied to the Devonians or the *Passage Beds* between the Silurian and the Carboniferous.]

In both the rocks of the reddish and greenish types are some good workable stones, that have been extensively used for building purposes, both in Ballaghaderreen and Charlestown. Some of them seem to be capable of producing good dressed work; but, as they have been principally used in rough walling, their capacities

have not been fairly tested; more especially as only the surface stones have been used in these buildings.

Carboniferous.—For the most part these occur as bands margining the older rocks, but in places in the limestone they are interstratified; some of them are fit for all cut-stone purposes, although none of them have come very prominently forward on account of the good-class limestone of the county, which is preferred by the workmen.

Meelick. Near Killala.—Brownish grey; quartz-grained, with little cement; easily worked, large blocks can be procured; extensively used in the piers and quay-wall at Ballina, and in the neighbourhood.

Crossmolina. A good freestone to the westward of the Deel river.

Between Foxford and Swinford are flags, some so thin that formerly they were used for roofing instead of slates.

Farm quarry. At Westport there is a peculiar stone. It occurs in the upper beds of the limestone quarry. It is thin-bedded and square, on account of the systems of joints that cut across it, these joint-lines being glazed with a film of quartz. One system of the joints is perpendicular, the other slightly oblique; but if the stones are properly selected and laid, the natural faces produce a perfectly even perpendicular wall, having a surface that looks like finely-cut limestone, laid in narrow courses; they were used in Lord Sligo's house at Westport, the dressings and other cut-stone being of limestone.

In the new church at Westport, Carboniferous Sandstones were used; but, unfortunately, dry stones and newly-quarried stones were mixed promiscuously, and consequently the drying and shrinkage of the latter have caused ugly open joints and uneven settlements.

The old church and round tower at *Aughagower* were built of the local red stone. It seems to have worked freely and well, but is not very durable.

Poulsharavogen. Six miles from Swinford.—This stone, although at the east of the county, is in general similar to that described as occurring at Meelick, near Ballina. In places, however, the stone is conglomeritic or pebbly; and, under such circumstances, Wilkinson considered it better adapted for cut-stone purposes. This

stone has been very generally used in Swinford, Claremorris, and the neighbourhood, and of it was built the round tower of Meelick, south of Swinford (not the Meelick previously mentioned, near Killala), of which the stones are now in good preservation.

Stones that have been used for flagging are recorded as follows:—Thin-bedded sandstones at *Carrickryne*, *Ballycastle*, *Meelick*, and *Carns*; used in Ballina. *Glenisland*, soft when quarried, but afterwards hardening; used in Castlebar; *Gormancladdy*, *Killedan*, *Balla*, and *Carrowcastle*; used in Swinford; and *Curveigh*, for use in Westport. There is a very thin, smooth flag, called "Dunmore slate," raised principally in the Lower Carboniferous Sandstone of Slieve-Dart, near Dunmore, partly in counties of Mayo and Galway. These, in old times, were extensively used in place of slate, as will be seen on the old houses in Castlebar, Crossmolina, Ballinrobe, and other places. This "slate" has been previously mentioned in the county Galway. Besides Slieve-Dart, it also occurs in some of the other localities for Lower Carboniferous Sandstone, as between Foxford and Swinford, but was not as extensively worked as in Slieve-Dart.

Sand and Gravel.—Good *pit sand* for building purposes can generally be easily obtained in the low country; the Eskers in the "Plains of Mayo" affording not only that, but good sand for *manure*, and *gravel* for road metal. The *river sands* are also good; they occur in various places along the rivers and streams. There is also *sea sand* in different places; near Ballina there is a considerable supply.

On the west coast of the barony of Murrisk there are *Æolian sands*, some parts of which are in cultivation and yield good crops, especially potatoes. There are also extensive tracts near Blacksod Bay, and smaller ones near Broadhaven; these seem to have been extensively cultivated formerly for potatoes and barley, but not so much of late years.

A good *glass sand* occurs near Belmullet, which has been used a little for glass manufacture.

MEATH.

To the east of the county, near Balbriggan, coming in from the county Dublin, to the north-east coming in from Louth, and to the north-west coming in from Cavan are *Ordovicians*—the last two being connected by the strip of similar rocks in which Kells is situated. In general sandstones are not exposed at the base of the *Carboniferous*, and in places there appears to be no room for them; they, however, appear near Oldcastle, to the westward of Kells, and between Navan and Drogheda; while Mr. Cruise states there is a small patch of conglomerate on the Ordovicians at Stramullen, at the mearing of the Co. Dublin to the west of Balbriggan. Elsewhere beds of sandstone have been observed interstratified with the limestone.

On the Carboniferous Limestone to the north, near Nobber, between Drogheda, Navan, and Maynooth, and near Trim, are outlying patches of *Coal-measures* in which are fair stones. At the extreme north of the county, near Kingscourt, there is a small tract of *Trias*.

ORDOVICIAN.—None of the sandstones or grits of this age seem to have been, or are at present, in favour for cut-stone purposes, nor have they been much used for general work, as the associated slate rocks, except in the tract near Balbriggan, are eminently suited for such work, and in old times and subsequently were, and are, much used.

CARBONIFEROUS.—In the small patches of Lower Carboniferous Sandstone, near Oldcastle and westward of Kells, there are sandstones of reddish, brownish, and yellowish shades of colour. These were used as quoins in the old church of Kells, while the round tower was nearly entirely built of them. They are not very durable, but are of an even texture, and have weathered evenly. Between Navan and Drogheda, along the margin of the Carboniferous rocks very similar stones have been quarried in places. They vary a little in colour; some are streaky or variegated, while they may be argillaceous or quartzose, some being very hard. They are not a good class of stone, yet they are very generally used, and the Round Tower of Donaghmore was built of them. Here, as also in the localities to the westward, some beds are capable of

being wrought into flags, and these have been used in Kells and elsewhere.

Hayestown. Fourteen miles from Kells.—Brownish to yellowish; quartz grains; calcario-silicious cement; not very durable; works easily.

To the north-west of Navan there are some sandstone quarries locally used.

In the tracts of Coal-measures there are some good stones reported; but if local use is ignored, none of them have been worked except in the Nobber district, and there only sparingly, as the bad roads and accommodation make the quarries difficult of access. Some of the thin-bedded sandstones, as near Garristown, make good and strong flags; English flags, however, being easily and cheaply obtained, seem to have prevented their being much worked.

Cortubber. Near Kingscourt; greyish-white; quartz grains; very little felspathic cement; finely granular; works freely and well.

Carricklick. Seven miles south of Carrickmacross. Greyish-white, but unevenly coloured; silicious grains; very little cement; fine-grained; works freely and well; large blocks can be procured. Lough Fea House was built of this stone; used extensively in Carrickmacross. A limited quantity of flags can be raised here, which can be manufactured into hearth-stones.

Trias.—The "Red Free" of this area seems to have been very little used, and only locally.

Sand and Gravel.—*Pit sand*, excellent for building purposes; is very general; although sometimes it is loamy. In the cutting for the Meath Railway an inexhaustible supply of sand and gravel suited for road purposes is exposed; some of it is good *manure sand*, but is not much used, so much of the county being under grass.

MONAGHAN.

Occupying all the central portion of the county are similar *Ordovicians* to those that have been described in Armagh and Cavan, which lie respectively to the north-east and south-west. Here, as in those counties, the grits are very little used, the

associated slate being much preferred for general purposes; although not capable of being used in dressed work. Fair flags have been raised in a few places, as in Dartree, which lies north and north-west of Clones.

To the south of the county, in the neighbourhood of Carrickmacross, is a small tract of *Carboniferous* rocks, principally limestone: this is overlaid by *Coal-measures*, and the latter, unconformably, by *Triassic* rock; the principal portions, however, of the outlier of the later rocks are situated in the neighbouring counties of Cavan and Meath.

To the north of the county there is a second area of *Carboniferous limestone.* And margining this to the southward, and lying on the Ordovician, is a narrow tract of *Lower Carboniferous Sandstone*, on which Clones and Monaghan are situated; while further northward are the rocks of the "FERMANAGH SERIES," or *Lower Coal-measures* of the Fermanagh type (*Fermanagh*, p. 560).

In the Fermanagh portion of the Slieve-Beagh district there are different quarries of former and present note; but eastward in this county there are none, although the "Fermanagh Sandstones" extend into it; also in places on the flanks of Carnmore superior stone have been procured. In Castleblayney, Monaghan, and Clones, most of the stones used for cut-stone purposes were brought from the quarries in the Fermanagh portion of Carnmore or quarries in the Lisnaskea district, or from the Clogher district (*Lower Carboniferous Sandstone*), Co. Tyrone. In the south of the county, at Carrickmacross and its neighbourhood, the sandstones have been brought from *Carrickleek*, Co. Meath.

Carnmore.—Yellowish-reddish. Chiefly quartz grains; ferriferous spots; somewhat friable; works freely. On the summit of the mountain there was an extensive quarry for millstones; which, after being wrought in the quarry, were let roll down the mountain, and conveyed to Scotstown, where there was a depôt. On the northern side of the hill there is a soft whitish freestone, and on the southern a hard reddish grit.

Knocknatally.—A good freestone, formerly extensively quarried for use in the neighbourhood.

Emyvale. Southward of.—*Fermanagh Sandstone* (?), used in Monaghan.

In the parish of Donagh, to the north of Monaghan, excellent

freestone was formerly quarried in different places, and the great entrance to Caledon House was constructed of this stone.

Sand and Gravel.—*Pit sand* of a good quality is very general in the county, while *river sand* can be obtained in the rivers and streams. *Gravel* can be procured from the Eskers: those in the Tehallan district being noted for their wearing qualities, they for the most part being made up of hard jasperry pebbles.

[In the high level portions of the counties Monaghan, Tyrone, Fermanagh, &c., there are gravel ridges that have been called "Eskers"; they are not, however, true Eskers similar to those of the great central plain of Ireland. The true Eskers are of marine origin, the ridges being due to the colliding of tidal currents, and all occur below fixed levels, which are the maximum heights of the Esker Sea; their height varying a little, as in the seas of the present day, the tides rising higher in the bays than in the open. The gravel ridges of the high levels, and in some places even on the lower levels, of the above-named counties, are for the most part of a different origin, being similar in aspects to the sands, gravels, and other drifts found in the valleys and plains and slopes associated with the Alpine regions, such as those found in connexion with the "Foot Hill" of the Canadian Rockies. In some of the low counties, Monaghan and Fermanagh, &c., the marine and glacial gravels seem in part to be mixed or to graduate into one another.]

QUEEN'S COUNTY.

The greater portion of this area is occupied by *Carboniferous Limestone;* but to the north-west, surrounding small exposures of *Ordovicians*, are tracts of *Lower Carboniferous Sandstone;* while to the south-east, in Cullinagh and the northern portion of Slieve-margy (Leinster Coal-field) are *Coal-measures*. The *Ordovician grits* are rarely used, even for local purposes, the associated slates being preferred.

Lower Carboniferous Sandstone.—In colour these are from whitish-yellowish to brownish, and streaked. Some are argillaceous, they not being as durable as those having a silicious cement. These sandstones have been very generally used in the neighbourhood. They have been largely used in Mountmellick, a soft, silicious stone in that neighbourhood being at one time extensively manufactured into chimney-pieces and hearthstones. In the churches of Abbeyleix, Slieve-Bloom sandstone and Ballyullen limestone were used in the dressings. Ballyfin House and the chief entrance lodge in the Slieve-Bloom district were built of local

stone; in the latter are some hastily selected, which have stood badly. At *Clonaslee* and *Rosenallis* there is a thin-bedded stone, very extensively used in the county for flagging; they cannot be obtained of large sizes, but are very dry; when first raised they are soft, but rapidly harden. Stones for cut work can also be procured; but, on account of the ungainly shapes of the blocks, are expensive to dress.

Clara Hill, Clonaslee.—Yellowish; very silicious; fine-grained; micaceous; ferriferous spots.

Tinahinch. Three miles from Clonaslee. — Greenish-white; silicious-grained; argillaceous cement; partially carbonaceous matter.

Glenbarrow. Three miles from Clonaslee.—Grey; silicious-grained; ferriferous spots.

Rosenallis Mountain. — Westward of Mountmellick. Very similar to the Clara Hill stone.

Ballysally. Ten miles from Roscrea, where it has been much used.—Yellowish to lightish-brown. Is soft when raised, but hardens on exposure. Works easily.

COAL-MEASURES.—In general, these stones are not now looked after, yet that they are capable of good work can be seen in the previously-mentioned doorway of Killeshin Church, Co. Carlow (page 537). In some of the ancient buildings a thin-bedded grit has been used, also in latter years at Cloggrennan. As those used at Cloggrennan were not suited for cut-stone purposes, other material was used for the dressings.

Cloggrennan.—Dark-greenish grey; fine-grained; close; dense; flaggy; not good for cut work.

Corgee and Hollypark. In the Collieries.—Good strong flags were formerly rather largely worked. These flags, on an average, could be raised 12 feet square, the largest raised being 22 feet long and 12 feet wide (*G. S. M.*)

Derryfore. East of Abbeyleix.—Olive, thick sandstones and flags.

SAND AND GRAVEL.—Both of excellent quality occur plentifully in the Eskers. In some of the streams coming down from both the Lower Carboniferous Sandstone and Coal-measure hills there are sharp silicious sands.

ROSCOMMON.

To the north and south-west of Lough Allen are *Coal-measures*—a small portion of the Connaught Coal-field. To the southward of these, extending from the north-west margin of the county eastward, past Lough Key nearly to the Shannon, are *Silurians* of the "Old Red Sandstone" type, which are margined southward and eastward by *Lower Carboniferous Sandstones.* To the west of the county, both north-east and west of Castlerea, and farther south-west in Slieve-Dart, are patches of similar rocks, as also south-west of Roscommon; while to the north-east of the same town, in a south-west and north-east direction, is Slieve-Baun, near which small exposures of *Ordovicians* are margined by *Lower Carboniferous Sandstone.*

The Ordovician grits, which are of small dimensions, are more or less inaccessible, and are very little used, even locally.

Silurian.—These occur in the Curlew Mountains. Of these there is a great thickness, and some of them are fair working stones; but in general they are hard, gritty, and of bad working quality and colour. They are not in request, as limestone is preferred; and if sandstone is required, those belonging to the Lower Carboniferous Sandstone are used.

Associated with these sandstones are felspathic tuffs. Although these are more of the nature of argillaceous than arenaceous rocks, they ought here to be mentioned, as in places the one graduates into the other. Some seem as if they would cut well; but as they are in general in somewhat inaccessible or inconvenient places, they have only been used for farm purposes.

Lower Carboniferous Sandstone.—In the different exposures of these rocks there are stones of more or less note. At *Tarmon*, near Boyle, there is a bluish-grey stone, hard and compact; but, on account of the numerous joints, it is incapable of being raised in large lengths. The strata varies from 10 to 24 inches in thickness; it has been used in many of the buildings in Boyle, but is more suitable for rubble than cut-stone purposes.

St. John's Hole. An historical quarry.—This lies north of the river near Boyle. Greyish; good, but hard; has been used extensively in Boyle and the neighbourhood, as in the bridge and

other public and private buildings. According to Wilkinson, it was also used in the old house of Rockingham that was burnt down some years ago; the new house, built in 1863 and 1864, is of limestone from Ballinafad, Co. Sligo.

In the bed of the river adjoining "St. John's Hole" is said to have been situated the quarry from which the stones were procured to build Boyle Abbey. Of this ancient structure, Wilkinson writes:—"Excellent work of every kind, from common dressed stones to carved mouldings and ornaments, and its lofty arches display a skill in construction far superior to the present day. The stone has resisted exposure to the weather well, some of the marks of the tools being still visible." Further, he states in reference to the site of the old quarry:—"It is likely that by well-directed efforts the bed of the river was temporarily diverted in order to get at stone which, from being constantly saturated, had not become so hard as that which was comparatively in a dry position."

[This raising of stones out of the bed of a river or stream seems to have been not uncommon with the early builders, as in different places holes are pointed out so situated, which tradition states were quarries where the stones were procured for adjoining structures. Besides other places, such is the case in the river at Drombogue, in the parish of Kilmacrenan, Co. Donegal, as from an excavation in the bed of the stream it is said the stones to build the adjacent Abbey of Douglas have been procured. A few years ago, during a dry summer, this hole was pumped out, and a rude set of steps were found from the surface to the bottom.]

In this county, as is so common elsewhere at the present time, the masons prefer the limestone for cut-stone purposes, so that the sandstone is in general only used for walling and rubble work, as it is easily roughly squared; in some cases it is used for quoins, window-sills, steps, and such like, while from St. John's Hole can also be procured excellent flags, with a natural smooth surface, of large sizes, and from 5 to 6 inches thick. They, however, are expensive and difficult to get at, on account of the necessary pumping to keep the quarry dry.

Felton. Near Boyle.—Yellowish; micaceous; ferriferous.

French Park. Within a mile of the town.—A silicious sandstone, used for building purposes.

In the tracts north-east and westward of Castlerea, good stones have been raised in different places, but no quarry more than of

local note has been worked. About three miles from the town there is a thin-bedded stone in the bed of the River Suck. It is in much request for walling, but is not good for cut-stone purposes. The stone can only be procured in the summer, when the river is low.

On the tract to the north-east, between the town and French Park, there are many large field-stones, or "tumblers," which have been extensively used for local works, especially bridges, as they split easily. They have been of considerable profit to the occupiers, who sold them to those who required them. In the same area, near *Bellanagane*, are finely-laminated stones like the "Dunmore slates," which in the vicinity have been used for roofing purposes; they are also found in the north-east portion of Slieve-Dart that enters into this county at the extreme south-west. In Slieve-Dart are also found the stones formerly so much wrought into millstones, but perhaps more in the Galway portion than in this county. Eastward of Bellanagane, between it and Mantua. is a calcareous stone containing *silicious nodules* more or less similar to rough agates and cornelians.

Sandstone can also be obtained in the tract to the west of the Suck and south-west of Roscommon.

In the parish of *Fuertry* there is a quarry of excellent gritstone of peculiar solidity and hardness.

In Slieve-Baun there are some good brownish and yellowish stones; but they are now principally used for local purposes, the limestone being preferred for dressed work. To the south-east of Strokestown, in the south-west portion of Slieve-Baun, there are stones particularly adapted for millstones, and fifty years ago they were made in considerable quantities for supplying the adjoining counties to the eastward of the Shannon.

Coal-measures.—These only occur at the north-west of the county. Some of the sandstones are reported to be of excellent quality, "equalling the Tyrone stone"; but they are so out of the way and inaccessible that very little is positively known about them. From the *Coal-measures*, however, are procurable excellent flags, somewhat like the Carlow flags, that formerly had a good sale; they were principally raised at Keadew and Arigna.

Sand and Gravel.—In the low country there are Eskers which give an inexhaustible supply of excellent *pit sand* and *gravel;* some

of these, when of limestone-gravel, are excellent as manure, others of a different character are not. *River sand* also occurs very generally.

SLIGO.

In the little promontory (Rosses) between Drumcliff and Sligo Bays is a small outlier composed of metamorphic rocks; while coming in from Mayo, near the centre of the west mearing, and extending north-east across the county, is a portion of the Ox Mountain range. These hills, as has already been mentioned, have a nucleus of metamorphic rocks, which are probably the equivalents of the *Arenig*, or possibly of the *Cambrian* ("Introduction," page 515; *Mayo*, page 587), and margining them in places are *Lower Carboniferous Sandstones.* To the extreme south, in a small portion of the Curlew Mountains, there are *Silurians* of the "Old Red Sandstone" type, coming in from the neighbouring counties, Mayo and Roscommon, which are margined to the southward by *Lower Carboniferous Sandstones.* To the east of the county are *Coal-measures*, a small portion of the CONNAUGHT COAL-FIELD; while to the westward of the main mass are small outliers, lying east and west of Lough Arrow. In recent times sandstone has not been much used in this county for cut-stone purposes, as in general limestone is preferred.

CAMBRIANS (?), ARENIG, AND ORDOVICIAN.—The rocks that probably are the equivalents of those of these groups are all more or less metamorphosed. There are, however, in them some quartz-rock and quartzyte, suited for heavy rough work and for road metal.

SILURIAN.—In the small area included in this county the rocks are similar to those adjoining, in the Co. Roscommon. They are of inferior quality for cut-stone purposes, being generally coarse and hard or argillaceous. They are, however, in places locally used.

CARBONIFEROUS. *Lower Carboniferous Sandstone.*—Some of the beds near Lough Gara, on the south slopes of the Curlew Mountains, are very similar to the rocks utilized at Boyle, in the Co. Roscommon; but here they do not seem to have been worked.

Westward of Ballysodare Bay and the neighbourhood of

Dromore West (parish of Kilmacshalgan) there are quarries of freestone.

To the west of the county, near Kilmacteige, and in other places farther eastward, margining the Ox Mountain range on the southward, there are in places fair-looking stones, but, as previously mentioned, not in request.

To the north-west of the Ox Mountains, in the neighbourhood of Dunowla, and to the south-west thereof, in the tract and strip of Lower Carboniferous and Calp (?) Sandstones, some of the stones appear as if they might be suited for dressing; but in no place are they sufficiently opened up to test their qualifications. South-east of Dromore, in *Doonbeakin* and *Ballyglass*, flags about 4 inches thick and up to 6 feet square have been quarried.

Coal-measures.—Reports state that some of the beds of stone in this area are of good quality. They, however, are so inaccessible that they are not properly known. From these hills, however, are procured flags of the same class as the "Arigna flags," which have been largely used throughout the county.

Sand and Gravel.—*Pit sand* is not very plentiful, and varies in sharpness. It can, however, be got good about four miles from Sligo. In some of the rivers and streams there is good *river sand* and *gravel*. *Sea sand*, which can be collected in great quantities along the shore, is an excellent manure for potatoes, but should be spread for some months before the crop is put in, as otherwise its proper effects are not experienced. In places near the shore-line is a stratum of shell sand or gravel, for the most part made up of oyster-shells. This, in some places, is at least 60 feet above the present high-water mark. This deposit is not only itself a valuable manure, but it imparts its fertilizing qualities to the sand above and below it.

TIPPERARY.

The sandstones of this county, although now not much heard of, have a history; as both in ancient and the present times they have been very much used in preference to other kinds, even in places outside the margin of the sandstone areas. At Cashel, the older structures (Cormac's Chapel and the Round Tower), are of sandstone, except that in the Tower some of

the lower courses are of limestone, but in the adjoining churches, which were subsequently built, limestone was used. Some of the sandstone hereafter mentioned, if known, would be more sought after than it is at present.

The major portion of the area is occupied by limestone. We find, however, to the north-east, a little S. S. W. of Birr (Parsonstown), the small but conspicuous hill of Knocksheegowna, mostly *Ordovician*, but margined to the north-east and south by *Lower Carboniferous Sandstone.* Somewhat similarly, in the Arva Mountains, that lie to the east of the south arm of Lough Derg; in the group comprising the Silvermine Mountains and Slieve-Phelim; in Slieve-na-Muck, to the south of Tipperary; and in the portion of the Galtees that is included in this county there are *Ordovicians*, margined by *Lower Carboniferous Sandstones.* The Hill of Cullen, to the north-west of Tipperary, is *Lower Carboniferous Sandstone;* but the rocks of Knockmeeldown, to the south-east of the county, are probably in part *Devonians*, coming in from the neighbouring Counties Cork and Waterford.

To the south-east, in the neighbourhood of Killenaule and north-east of it, are *Coal-measures*, the EAST MUNSTER COAL-FIELD; while south-westward of the principal area are small, detached patches as outliers, which lie north of Cashel; north-east and south-west of Fethard; north-west of Clonmel; in Slieve-na-Muck, brought down by a great fault against the *Ordovicians;* and at Ballyporeen, in the valley between the Galtees and Knockmeeldown.

ORDOVICIAN.—These are, in general, in more or less inaccessible positions. When otherwise, nearly invariably the grits are in bad repute, as the associated slate rocks are preferred for local building purposes.

DEVONIANS.—The rocks of Knockmeeldown seem to be in part the representatives of the *Devonians* of the County of Cork, that is, the Passage-beds between the Silurians and the Carboniferous; while it is not impossible that the lower rocks of the Galtees to the northward, and of Slievenaman to the north-eastward, may be in part of this age, as the great thickness of the arenaceous rocks under the *Carboniferous Limestone*, as found in all these places, suggests that the Passage-rocks may be in part represented.

Knockmeeldown. In different places brownish, reddish, and yellowish. Free-working; durable. Has been extensively used in

Cloghreen, although the latter is in the limestone. A brown sandstone from these hills was used in the ancient castle at Cahir.

Mount Anglesey. A few miles from Cloghreen.—Brownish-yellow; silicious-grained; argillaceous cement; fine, but granular; friable; works freely and well; used for quoins, jambs, and other dressings; can be raised in long scantlings, and is capable of long bearings.

In the slopes of the Galtees, included in this area, good stones occur in numerous places: they vary from whitish to reddish and brownish in colour, some being more silicious than others. In general they work freely, and have been used in Cahir in preference to the limestone. These were used in the repairs of the old castle some forty or fifty years ago.

Carboniferous.—*Lower Carboniferous Sandstone.* These stones range from coarse reddish or brownish conglomerate to fine sandstone, in shades of light yellow, reddish, and brown or purplish. In Clonmel, where sandstone has been most used, it has been procured from the other side of the Suir, in the Co. Waterford. A similar remark is applicable to Carrick-on-Suir.

Tinnakilly. Six miles north-east of Carrick-on-Suir.—Yellow to brownish; silicious-grained; with little cement; ferriferous; very slightly micaceous. From here, and from Millvale, Co. Waterford, have been procured most of the sandstone used in Carrick.

Dundrum. About a mile from.—Yellowish-grey; very good texture; suitable for all kinds of dressed work. Mr. Sharp, the well-known Dublin builder, states that he believes this stone would be very generally used if it were known.

Drumbane. About seven miles southward of Thurles.—Whitish or light-grey; quartz-grains; argillaco-silicious cement; slightly ferriferous; works freely; can be raised in large scantlings. Was used in the Court-house, Nenagh, twenty miles distant, and in the Model School, Clonmel. This, like the Dundrum stone, ought to be more generally known; it is an admirable material, more durable than limestone, and very suitable for staircases, as it can be obtained in nearly any scantlings, and is capable of long bearings.

Carrick. Near Roscrea.—Light-brown; silicious; very little cement; fine-grained; dense.

In Roscrea, both in ancient and modern times, the local sandstone has been extensively used. A better quality has been brought from Ballinsally, Queen's County; but the old structures, as mentioned by Wilkinson, seem to be built of the local stone. In Cronan's Church and the Round Tower, the original working, as far as now preserved, seems to have been good; but the stones were not well selected, some now being very much disintegrated. The stones in the old castle are fine and thin-bedded, and although not so much weathered, they seem to have been weak, as some are cracked at their edges.

In other localities where the *Lower Carboniferous Sandstone* occurs margining the Ordovicians, good stone can in places be procured, and has been used locally. The conglomerates and coarse sandstones have been in request for bridges and walls, for which they are admirably suited, while in places they were formerly wrought into millstones. Thin-bedded stones, used as flagging in Cashel, are raised near Dundrum, and similar stones for flagging in Tipperary have been procured at Shrough, seven miles distant; they have also been used extensively in the military barracks there, and at Fermoy, Co. Cork.—(*James Newstead.*)

[As very superior stones are known to exist near Dundrum, and at Drumbane, southward of Thurles, similar veins ought also to occur elsewhere in the county margining the tracts of *Ordovicians*. But they have not been looked for, the stones of this county, as already mentioned, not being in the market, and, except locally, are not of note; but if inquired after they would probably be more in request than some now sought after.]

COAL-MEASURES.—In different places there are good stones for walling and rubble; but as they in general hammer badly, the quoins, sills, and other stones for dressed work are procured from the Devonian or Yellow Sandstone quarries.

In places in the Killenaule district, below the lowest coal, good flags can be raised.

SAND AND GRAVEL.—Near Roscrea, Thurles, and Tipperary, are Eskers, from which can be procured an unlimited supply of *pit sand* and *gravel.* Good sand can also be got near Clonmel and Nenagh, and an inferior kind near Cashel. *River sand* occurs in places in the Suir and the other rivers and streams.

The Esker sands, and also a marly gravel was formerly extensively used as manure. The latter was called *Corn gravel,* as it

gave excellent crops of wheat; but since the change in the climate which prevents the wheat from properly yielding and ripening, and the consequent falling off in that crop, it is not much used.

TYRONE.

This, at the present time, is the premier sandstone country: not, however, as regards quantity, but as to the quality to suit the present market; and also as to variety, they being of different colours, textures, and hardness, and belonging to various Geological groups and sub-groups.

To the northward, extending from near Omagh, north-eastward into Londonderry, is the tract of metamorphic rocks, suggested by Dr. Hinck as possibly of *Laurentian* age; but, as shown in the "Introduction" (page 515), more probably the equivalents of the *Arenig*, or even possibly of the *Cambrian*. In the vicinity of Pomeroy, against these rocks is a small tract of rocks that possibly may in part represent the *Llandovery*, which, as given in the Table of Strata (Part I., page 204), are the Passage-beds between the Silurian and the Ordovician; these rocks, however, are evidently nearer allied to the last than the first.

On the southward of these strata is a considerable and wide tract of *Silurian*, of the "Lower Old Red Sandstone" type—the eastern portion of the area already mentioned when describing Fermanagh (page 560); and still further to the southward, in places margining these rocks, is a narrow band of *Lower Carboniferous Sandstone*.

North of the Tyrone Coal-field there is a tract of *Calp Sandstone* brought up by a fault, while there is a second south-west of Dungannon (Dungannon Park). Farther south-westward, north-east and south-east of Aughnacloy, are tracts of somewhat similar rocks that have been classed among the *Calp Sandstone;* but it should be pointed out that they are also more or less like the rocks of the *Fermanagh Series* (Lower Coal-Measures) of the Slieve-Beagh district, counties Fermanagh and Monaghan (page 561); while in the neighbourhood of Aughnacloy they appear to join into one another. It seems possible that in the latter neighbourhood the geology has not been properly worked out, and hereafter (north of the Tyrone Coal-field), it will be found that the Coal-

measures and Calp Sandstone are brought together by a fault, a downthrow to the south-eastward.

[All these lithologically similar rocks to the north-east of the Blackwater (Aughnacloy) are called on the new maps *Calp*, while west and south-west of that river they are called by the unappropriate English sub-group names, *Yoredale beds* and *Millstone grits*.]

The well-known sandstones of the Co. Tyrone are all of Carboniferous age; but they may belong to the *Lower Carboniferous Sandstone*, the *Calp*, or the *Coal-measures*. The rocks in the neighbourhood of Aughnacloy, as already mentioned, may belong to either of the latter groups; here, provisionally, they will be described with those of the Calp. The Calp is of the two types, the ordinary, and the "Ulster type;" the rocks in these will be given separately.

[The subdivisions of "Upper and Lower Calciferous Series" adopted in the *Geological Survey Memoirs* are only lithological; the reddish pebbly rocks forming the latter. These dark-coloured rocks may, however, occur on any geological horizon, their colour and composition being solely due to islands, or other shore lines in the Carboniferous sea, they always being found adjoining a protrude of the older rocks.]

These rocks have been used in the county—very generally in Dungannon, Coalisland, Clogher, Omagh, Cookstown, Castlederg, and Caledon; while in Strabane, and other places in the schist regions, they are used for quoins and other dressed-stone purposes. At Baronscourt they were used, except the Portland stone for the staircases, and in a few other places. Out of the county they have been extensively used for cut-stone purposes.

Near Benburb, at the south margin of the county, are sandstones that have been said to be of *Permian* age; but on account of the assemblage of fossils in these and the associated rocks, and also of their position, Baily and the writer have suggested that they must belong to the *Carboniferous*.

In the northern portion of the county, at Cookstown and Kildress, at Omagh and south-east of Strabane, are tracts of *Calp*, of the "Ulster type" (*vide* "Introduction"); while north of Dungannon, and further northward at Annaghone are *Coal-measures* (TYRONE COAL-FIELDS). Near Cookstown and Coagh, and extending southward past Dungannon into the Co. Armagh, *Trias* ("Red Free") is found.

The Ordovician grits are very little used even for local purposes, the associated slates being preferred for ordinary work. At Strabane, Castlederg, and other places in the north of the county the metamorphosed Ordovicians (*Micalyte*, *Argillyte*, &c.) are used for walling, the cut-stone work nearly invariably being Carboniferous Sandstone. Near Strabane flags are procured.

Silurian.—These range from conglomerate to fine sandstones; in general being silicious, but often argillaceous, or even carbonaceous. Similarly, as in the Co. Fermanagh, they have been used a little for cut-stone purposes, and are very suitable for coarse work, such as bridges and walls. Formerly, in some places, the very silicious varieties were wrought into millstones.

Lacagh. About two miles south-east of Fintona.—Purple and reddish; conglomeritic; yields sills and quoins; used in the building of Fintona new bridge.

Dungoran. Near Fintona.—Yellowish; grains white quartz; a little argillo-silicious cement.

Raveagh. Near Fintona.—Brown; makes good rubble; used in Raveagh House.

Dundiven. Three miles south-west of Fintona.—Cream colour, greyish-white, and greenish-grey. Rather argillaceous and felspathic; partly calcareous; granular; fine-grained; free-working.

Lackagh. Three miles from Fintona.—Dark-purplish; semi-crystalline.

Pomeroy. A mile from.—Dark-purplish grey; semi-crystalline; granular; micaceous; works fairly well.

Lower Carboniferous Sandstone.—Generally greyish or yellowish in colour; some, however, reddish; more or less silicious; unequal grained; works freely, but soon wears the tools. In places some of the more silicious varieties were wrought into millstones.

Derrynascope. One mile from Augher.—Greyish and yellow; silicious-grained, with, in some beds, a reddish felspathic cement.

Dernasill. Four miles from Augher.—Greyish-white to yellowish; silicious; argillo-silicious cement; granular; micaceous; in some beds ferriferous.

Altaven. Five miles from Augher.—Greenish-white, with yellow seams; very quartzose; unequally grained.

Ballymagowan. One mile from Clogher.—Yellowish; white

silicious grains; a little felspathic cement; when ferriferous they have a reddish tinge.

Elderwood. Three miles from Fivemiletown.—Reddish; silicious grained; felspathic cement.

Cavey. One mile from Ballygawly.—Yellowish; silicious; a little cement; fine-grained; ferriferous. The conglomerates near Ballygawly were formerly wrought into millstones and flax-crushers.

CALP (*Ulster type*).—Many of them are beautiful stones—creamy or yellowish in colour, or with a bluish tint. In general they are free-working, open-grained, and capable of producing good work; some, however, are not suitable for heavy bearing. From the ancient buildings in which they were used they seem to be very durable.

These sandstones occur in limited thicknesses of strata, the "over-bearing" or cover-rocks being limestones or shale. This, as the quarry is worked in on the dip (which is low) of the stone, very often becomes excessive, so that the expense of removing it may become greater than the value of the stone. In other quarries the good stone occurs in more or less lenticular or other masses, adjoining which the stones are inferior. For these causes, quarries once famous are now worked out or abandoned.

Cookstown. In different quarries in the vicinity of.—Yellowish, creamy, or with a bluish tint; silicious-grained; a little argillo-silicious cement; open-grained; slightly micaceous; soft, and not suitable for heavy bearings. Mr. Dickinson states:—"Some of the beds are hard and excellent for all kinds of masonry." From Tamlaght quarries were procured the stones used in the Lower Bann navigation works, while those used in the building of Killymore Castle came from the quarry nearly a mile north-west of the workhouse. Stones from the Cookstown quarries were also "used in the Provincial Bank, Belfast: a light, tough sandstone, hard to dress, and does not stand."—(*W. Grey.*)

Kildress. Stones very similar to those of Cookstown.

Loughrea. South of Cookstown.—Similar stone.

Trinmadan. Nearly two miles from Gortin.—Yellowish; quartz grains; argillo-silicious cement; granular.

Carrickmore, four miles from Gortin; *Douglas Bridge*, eight miles from Strabane; *Mullinavarra*, three miles from Castlederg; *Derry-*

guinna and *Longfield*, where most of the stones used in the building of Baronscourt were procured; and *Drumquin*, west of Omagh. In these quarries the stones are more or less similar to those of Cookstown. From the Drumquin quarries were procured the stones for the pillars in the Omagh Courthouse.

At *Cookstown*, *Drumquin*, and *Carrickmore*, especially the latter, flagging has been procured for the neighbouring towns.

Calp.—These rocks occur to the north of the Coalisland-Coalfield, and in tracts of less or greater dimensions in the county, west and south-west of Dungannon. As pointed out previously, they are in some respects similar to the rocks of the *Slieve-Beagh* district.

Bloom Hill. About four miles north of Dungannon, and three from the Donaghmore Station, Great Northern Railway.—Two quarries, of different qualities and colour. Creamy, greyish-white, and reddish-yellow; the latter, or *Red-beds*, being inferior. Principally silicious-grained, very little cement, fine-grained. Some beds, especially the reds, are in part argillaceous and micaceous or ferriferous. Mr. Hardman states:—"The stone much resembles that at Gortnagluck and Carlan (presently mentioned), is equally good for building purposes, and has been much used."—(*G. S. M.*) It has been much used in Dublin and other places. In the Belfast banks, Donegal and Ballyshannon, it has been found very durable.

Gortnagluck and *Carlan.* About half a mile apart, and apparently on one set of strata, about two miles from the Donaghmore Station, Great Northern Railway.—Of slightly varied colour and quality; creamy, yellowish, greyish, white and reddish—the *Red-beds* being inferior. Silicious-grained; very little cement; slightly micaceous and ferriferous; cuts freely and well; can be raised of good scantlings; gets hard from exposure, and is durable when worked on its bed. It is a favourite for cut-stone purposes in Ballymena, Co. Antrim, where it is considered the best of the "Dungannon stone;" the Belfast people, however, seem to prefer the Ranfurly (Mullaghana) stone. It was used for all cut-stone purposes in Raveagh House, near Fintona; Convent of Mercy, Ballyshannon, Co. Donegal; Roman Catholic Church, Magherafelt, Co. Derry; Harbour Offices, Londonderry; and in various other places.

Spademill. An old quarry, now not of note.—Some of the beds excellent for scythe stones.

Ranfurly or *Mullaghana.* Joined by a siding to the Dungannon Railway Station.—Creamy and yellowish; silicious; very little cement; fine-grained; lasting colour; difficult to work. The quarry, after being for some time closed, was recently worked, but is now (1887) again closed. Was used in the Post Office and Northern Bank, Belfast, and Northern Bank, Fintona; also in the addition to the Royal University, Dublin, where it has been found durable and to retain its colour.

The "Dungannon stone," from some one or other of these different quarries, has been extensively used in Dungannon. According to a list, to which I am indebted to Mr. Dickinson, some of the principal buildings are: the Provincial Bank, Parish and Roman Catholic Churches, Shiel's Institution, Police Barracks, and Parochial Hall. Elsewhere it has been used at Roxborough Castle, Moy; bridge over the Ballinderry river, near Coagh (cost £5000); the clock tower, and St. Patrick's Church, Belfast. "These Dungannon stones, with those from Dungiven (Co. Londonderry), and Cookstown, were used promiscuously in the public offices (Post-office, Customs, and Inland Revenue), and the Apprentice Boys' Memorial Hall, Londonderry; also with the Dungiven stone only in the Lunatic Asylum, where the stones from each quarry were used in a separate building. *Bloomhill,* for the gate-lodge and offices; *Gortnagluck,* for two separate wings; *Carlan,* in the doctor's residence; and the *Dungiven,* in two octagonal wings and the front of the old portion of the asylum. In the military barracks, Omagh, Dungannon stone, of the inferior quality known as the *Red-beds,* was used; it works easily, but is not durable."—(*J. Cockburn.*)

Aughnacloy.—Greyish to yellowish; silicious-grained. Also quarried three miles south-east of Aughnacloy.

Glencall. One mile from Aughnacloy.—Greyish-white; slightly stained with iron; very silicious; silicious cement; a little mica.

Brantry. Six miles south of Dungannon.—Purplish-grey; slightly variegated; semi-crystalline; granular; micaceous.

COAL-MEASURES.—Some of the arenaceous rocks of this subgroup, unlike those that in general occur in the measures of Munster and Leinster, are free-working stones. Rarely, however, can they be raised profitably, on account of the "clearing" or

"over-bearing" of drift, or useless rocks, that overlie them; they are, however, inferior to the Calp Sandstone, and no quarry in them seems now to be worked.

Edendork. Two miles northward from Dungannon.—Reddish; fine-grained; slightly micaceous; soft; not now worked.

Sand and Gravel.—Eskers extend from Killymoon, near Cookstown, to Dungannon, and thence by Ballygawly, Clogher, and Fivemiletown into the county of Fermanagh; in them there is an unlimited supply of good *pit sand* and *gravel.* Some of these so-called Eskers, as in the Pomeroy valley, are evidently *Glacial river gravel.* (*See* Monaghan, p. 592.) Good *pit sand* can also be procured near Gortin. *River sand* occurs in the Foyle, at Lifford Bridge, near Strabane; in the Moyne, near Omagh, and elsewhere; near Castlederg, and in many of the rivers and streams from the hills.

WATERFORD.

Occupying a considerable area in the east of the county is a large tract of *Ordovicians.* Overlying this, to the west, in the Monavullagh and Comeragh Mountains, are massive conglomerates, sandstones, and slates, which to me seem to be littoral accumulations of the West Cork and Kerry Devonians.[1] If this suggestion is correct, portion of the younger rocks, in the Galtees, to the northwest, and Slievenaman to the north, ought to be also Devonians. These Devonians, as in Cork and Kerry, seem to graduate upward without any quick or decided change, into the *Yellow Sandstone* or *Lower Carboniferous Sandstone;* as in general the dips in both groups of rocks are similiar. This, however, is not always so, as in the neighbourhood of Glenpatrick, to the southward of Clonmel and Kilshelan, there is a sudden change in the direction of the dips, the later rocks dipping northward at low angles, and the older southward at high ones. This change may possibly only be due to a line of fault; but it may be caused by an unconformability: it should, however, be more carefully examined into. However, to the southward in these hills, and also

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[1] John Kelly, I think, was of a similar opinion, but I do not know exactly where he stated it.

farther west in Knockmeeldown, one group appears to graduate into the other; the Yellow Sandstone margining the Devonian. The Yellow Sandstones also occur in places eastward (estuary of the Suir), and in a band to the northward of the Ordovicians.

In the south division of the county, that is south of the valley from Dungarvan to the Blackwater at Lismore, there are, east and west, ridges of sandstones, separated by troughs of Carboniferous limestones or shales; and in these ridges, as in Cork, farther west, if there is a sufficient thickness of strata exposed, the Yellow Sandstone (*Lower Carboniferous Sandstone*) is found to graduate downward into the Devonian.

In the Bonmahon mining district, in two or three places, very small patches of red or purplish conglomerate and sandstone have been found lying on, or partly in, the Ordovician. These must be either of Silurian or Devonian age, probably the latter: that is, small outliers of the Comeragh conglomerates.

ORDOVICIAN.—The major portion of the grits and sandstones are not fitted for general cut-stone purposes, although some dress on the bedded surfaces; nor are they in much repute for common walling purposes, the associated slate being preferred, except in a few cases. There are, however, some green tuffose sandstones that are associated with the Exotic bedded rocks; these do not seem to have been much utilized in this county, although very similar rocks have been used during ancient and modern times, in the Co. Wexford, where they have produced good and durable work.

Grange Hill. Waterford.—Here there is a slaty grit that has been much used. It is very strong and hard, but very difficult to raise, on account of the absence of back joints; it dresses well on the face, but not on the edges. It was used in the ancient round castle, called Reginald's Tower, which shows the durability of the stone. The dressed work round the opening in this structure is of Carboniferous Sandstone, which has weathered much more, but evenly, than the Grange Hill stone.

DEVONIAN AND CARBONIFEROUS.—In the Co. Cork, the *Silurians* and *Devonians* are intimately connected, and hard to separate. They were, therefore, grouped together. In this county, however, it is not the beds below the *Devonians* but those above them that are intimately connected. It therefore is expedient here to group

the *Devonians* with the *Lower Carboniferous Sandstone* (Yellow Sandstone), and to describe the stones that occur in both together.

These stones are very generally used throughout the county, either for cut-stone or rubble purposes. The stones usually are shades of brown, green, and yellow. In the west of the county different varieties of stone are very much mixed up; as quite distinct stones very often occur together in one quarry. At *Skorough*, eastward of Lismore, in one quarry, there are four varieties, interstratified, ranging from finely-laminated slate to a gritty sandstone. A soft, earthy, felspathic, and micaceous stone, from Ballysaggart, was used in the dressings of the Roman Catholic Church, Lismore; while, about three miles eastward of the town, in one quarry there are roofing-slates, good flags, and freestone, all of which were formerly worked. These slates, however, were eventually cut out by the Welsh slate. In the same townland, but nearer Lismore, there is a stone fit for cut-work; but it varies in quality, the best being in beds from two and a-half to three feet thick. There are also other quarries, nearer to the town, but difficult of access. For the buildings in Lismore sandstone has principally been used; but in the church erected about fifty years ago limestone was used, and also in the mullions and windows of Lismore Castle.

Glenniveene. About five miles from Lismore.—Flags; difficult to dress, as they are liable to chip at the edges.

Slieve-Grian. In different places.—Light-coloured, silicious, felspathic cement; slightly micaceous; even-grained; porous; good quality; works freely. Very generally used for dressed work in Dungarvan, from which the quarries are distant some seven to nine miles.

In *Cappoquin*, the stone most used is a local thin-bedded, gritty, silicious, speckled sandstone.

Cappagh.—An excellent dry stone, but difficult to work, as it has no regular bedding or soles. Used in the new house at Cappagh. Green flags have also been procured in the neighbouring hills.

Ballyharahan and *Killongford.* Near Dungarvan.—Brownish and yellowish, but more usually variegated. Generally soft, fine, argillaceous, and micaceous on the bedded surfaces; porous, and easily worked. In the quarries there are some subordinate, felspathic, and more coarsely-grained beds, from twelve to fifteen

inches thick. Generally used, but often with limestone, for rubble and walling in Dungarvan, the dressing being Slieve-Grian stone or Whitechurch limestone.

Ardmore.—The ancient round tower, as pointed out by Wilkinson, "is a fine example of cut-stone masonry, and demonstrates the durability of the sandstone of the neighbourhood." "Walling in squared coursed work of reddish-grey sandstone, is in good preservation."

"*Clonmel Quarry.*" Half a mile from Clonmel.—Whitish to greenish; silicious; in some beds an argillaceous, silicious cement; works well. The sandstone generally used in Clonmel.

Millvale. Two miles from Carrick-on-Suir.—Reddish; silicious; with a little silicious cement; ferriferous. Has been largely used in Carrick.

Waterford.—The conglomerate that lies unconformably on the Ordovicians seems to be rarely used, except for road metal. About a mile from the town there is a quarry in reddish-brown, good sandstone; but as it is difficult of access, it is not now much used.

Brown Head Promontory. East of Tramore Bay.—Dark-red sandstone. It is very effective, with granite mouldings, in Newtown House, near Waterford.

To the east of the county, adjoining the estuary of the Suir and Barrow, there are limited tracts of conglomerate and sandstone well adapted for heavy work, such as piers and sea-walls, as they are capable of being raised in large squarish blocks. At Dunmore East there are good workable beds in the red sandstone cliffs, which have been locally used in sea-works; in the town and the coastguard-station: they are not durable. New Ross pier, Co. Wexford, is built of this class of stone; which was brought either from one of these tracts, or from that at Ballyhack and Arthurstown, Co. Wexford. Mr. Langrish states:—"The stone, from its hardness and roughness of surface, ought to make splendid coping for a quay wall, preferable to granite or limestone, which wear quite smooth."

Sand and Gravel.—*Pit sand* and *gravel* are dispersed over the county, but generally not in quantity. In many cases the sand is very fine. At the round hill near Lismore there are good building and moulding sands, the latter used in the Cappoquin Foundry; also close to Ballyduff railway station. *River sand* is found in some of

the rivers and streams. For Waterford, they procure it about sixteen miles up the Suir, near Portlaw. "At Bonmahon there is a *sea sand* (Æolian) fit for almost any building or concrete. It is artificial, being due to the washings from the stamps when the copper mines were at work."—(*W. S. Duffén*).

Glass.—Early in the century glass bottles were made opposite to Ballycarvel; and subsequently, about fifty years ago, there was a large glass manufactory. The "Gatchell or Waterford glass" was famous, this "Irish glass" having a name even in India, to which it was largely exported. It ceased about 1845, after the death of George Gatchell, as on his death the lease of the premises expired, and the landlord wanted to double the rent. This, combined with his widow wishing to retire to England—her native country—broke up the industry. A sand for cutting purposes is said to have been brought from the Co. Kilkenny, and the rest from the Isle of Wight, England.

[Flint sand is the principal ingredient in flint glass. There is also red-lead, pearl-ash, manganese, arsenic, &c., the ingredients and the quantity of each used depending on the metal-mixer. The metal-mixer locks himself into his room, and there mingles the several compounds. If his talent in this department leads to a good result, as was always the case in the Waterford glass when Walter Purcill was the metal-mixer, such a man can almost carry everything his own way.—(*George Miller*).]

WESTMEATH.

This area is occupied nearly solely by *Carboniferous* limestone. At Sion Hill, however, north of Killucan, there is a very small exposure of *Ordovician*, margined by *Lower Carboniferous Sandstone*, the latter rock also appearing in a few scattered exposures near Moate, and near Ballynacarrig, to the north-west of the county. These sandstones are of very limited extent, and are only used in their intermediate vicinities.

South-west of Mullingar, in the parish of Lynn, are some quarries of calcareo-argillaco-arenaceous flags.

Sand and Gravel.—*Pit sand* and *gravel* are common throughout the county, and of a fair quality.

WEXFORD.

Under the major portion are *Cambrian*, *Ordovician*, and *Granite; Carboniferous* rocks only occurring in very limited tracts, as near Wexford Harbour, in a band across the baronies of Forth and Bargy, at Baginbun, in Hook Promontory, and on the edge of the estuary of the Suir, westward of Fethard, and at Ballyhack.

CAMBRIAN.—These rocks are in part metamorphosed. Some of the more hornblendic patches have been said to be of Laurentian age; as, however, such patches would be *Mosaics in the Cambrians* (to quote Dr. Callaway), it is far more probable that all are equivalents of the Cambrian (page 516). In these there are quartz-rock, quartzyte, and grits, mostly unshapely, and more suited for road metal than any other purpose. Some of them, however, can be raised in large blocks, suitable for sea-walls, for which they have in places been used, as in the embankments of the north and south intakes.

ORDOVICIAN.—Usually the grits are only suitable for rough local walling; in places, however, there are more or less calcareous tuffose sandstones associated with the interbedded Exotic rocks. These, as exhibited in the ancient structures, such as the old buildings in Ferns and Wexford, if well selected, are durable stones; and are also capable of fine sculpturing, as seen in the beautiful Egyptian doorway of the little church of Clone, about a mile southward of Ferns. Of late years they have been used in Clone new church, and in some of the bridges of the Dublin and Wexford Railway. It is a stone that ought to be more generally used, being very free-working, easily raised, and durable if well selected. When first worked, the colour is greenish-grey; it then becomes discoloured, but this discolouring seems subsequently to wash out, if we may judge of the stones as they now appear in the old buildings. If, as in the States of America, sawing was introduced into our quarries, this would be an admirable stone to be thus worked, as it is light and porous, and might be cut into sizes from the scantling of brick to those of quoins, sills, &c. It seems capable of heavy and long bearings.

Ballymore, near Gorey.—A sandstone quarry; but it is jointy,

and does not work well; Bagnalstown granite was preferred to it for the dressing of Kilternel Church, Courtown.

Carboniferous.—*Lower Carboniferous Sandstones* are yellowish and reddish shaly sandstones, and more or less coarse conglomerates. In the neighbourhood of Wexford Harbour they have been quarried, principally near Castlebridge, at Artramon, at Saunder's Court, and at Park. From the latter were procured the stones for the "Father Roche's Churches" in Wexford. It is a pebbly sandstone or fine conglomerate, and gives a picturesque and unique aspect to the buildings. As pointed out by Wilkinson, it is a peculiar stone, and must be understood by the masons, as under ordinary circumstances it would be rejected, and an inferior stone preferred. If, however, it is dressed immediately on being raised it works well, and makes sound, durable, and dry work. It was in part used in the old abbey at Wexford. As it can be raised in squarish blocks, it is also very suitable for quay walls, and such like large work.

A more or less similar stone, and a yellowish sandstone has been quarried in places in the baronies of Forth and Burgy, especially near Duncormick.

At *Baginbun*, in the *Hook Promontory*, south of Duncannon, and at *Ballyhack*, there are massive conglomerates and sandstones that can be raised in large blocks suitable for piers and such like, having been used, among other places, in the pier at Kilmore. Near Arthurstown are quarries of good grits, formerly much used for millstones. (See *Waterford*.)

[In most of the old ecclesiastical buildings in this county, a stone very similar to the caenstone has been largely used. Some caen may have been used; but, as pointed out by Mr. Robertson of Kilkenny, the stone is probably Doulting stone, from near Glastonbury, England. (See *Kilkenny*.)]

Sand and Gravel.—In this county, below the 250-feet conture level in places, there are vast accumulations of *manure gravel*, a shelly sand, formerly much used for bedding cattle, and afterwards as manure. This, to the northward near Gorey, and between Enniscorthy and Newtownbarry, graduates into ordinary sands and gravels, those in the Slaney valley being for the greater part limestone. There are also, for miles along the coastline, large tracts of Æolian sand; this, also, in places was formerly

used as manure on the "marl land," being considered most beneficial if brought from below high-water mark "with the sea in it:" that is, when wet and salty, it was considered better than if the salt was worked out of it.

In the Gorey district, and the upper portion of the Slaney valley, there is good *pit sand* and *gravel*, also at the Deeps, to the northward of Wexford, and in some other places. Good *river sand* can be procured in limited portions of the Slaney, and the other rivers and streams.

WICKLOW.

In this county sandstones or allied rocks that are now in favour for cut-stone purposes are few. The area is solely occupied by *Granite*, *Cambrian*, and *Ordovician*, the latter in a great measure metamorphosed.

In the CAMBRIAN at Bray Head, and also in the hills north-east of Togher or Roundwood, there are extremely hard green grits, and, in other places, the quartz rocks are well suited for road-metal; but some of the more regularly-bedded and granular varieties of the quartzytes might possibly be worked.

Glencormick. North of the Great Sugarloaf.—Warm cream colour; fine-grained; silicious, thin-bedded; cuts easily and well. Extensively used in Bray and other places in that neighbourhood.—(*T. B. Grierson.*)

In the less altered ORDOVICIANS, near the west margin of the county, are interbedded green tuffose sandstones, allied to those described in the Co. Wexford. Some of them were used in the old structures, and gave good, durable work. At the Seven Churches, Glendalough, in the building now called "St. Kevin's Kitchen," a metamorphosed stone, apparently of this class, was cut to the slope of the stone roof, besides being worked in other ways, as in a carving over the doorway of the structure now called "The Library."

SAND AND GRAVEL.—*Pit sand* and *gravel* occurs in places in nearly all the valleys; and from the washing of them by the streams, good *river sands* are produced.

For long distances along the seaboard are greater or less accumulations of *Æolian Sand.* At Arklow, the fine sand drifted

through the rampart at the Chemical Works is sent to Dublin to be used in the sawing of blocks of stone and for polishing. This, as mentioned in the "Introduction" (page 529), suggests a new industry.

Glass.—At Melitia, westward of Shillelagh, and about two miles from the ancient church of Aughowle, there is the site of an ancient glass-house, to which attention has recently been directed by the Rev. J. F. M. Ffrench (*Jour. Roy. Hist. Arch. Ass., Ire.*, vol. vii., 4th ser., p. 420). In the neighbourhood there is a sand which the glass-workers of Dublin state, "if ground down, it ought to be a suitable sand." Glass seems also to have been manufactured at the Chamney Iron Furnace, Shillelagh, as some years ago, when removing part of the old ruins, a quantity of glass slag was found.

In the townland of Ballymanus, westward of Aughrim railway station, there is a dyke of fine white sand, evidently a decomposed felsitic rock. This has been submitted to the glassmakers at Ringsend, Co. Dublin, who state it is too clayey for clear glass, but ought to be excellent for black glass. To meet the Dublin market it would have to be delivered at about 3*s*. per ton.

NOTES ADDED IN THE PRESS.

CO. DONEGAL.

Dunmore Head; and *Croagh*—Innishowen—one and a-half miles south-west of Dunmore Quay, and two and a-half miles south-west of Culduff. Bluish-grey quartzose flags can be raised in squares from 6 to 10 feet, and of all thicknesses, some thin enough to be used as roofing-slates.—(*A. M'Henry*).

Kindrum — Fanad-within-the-Waters — west of Kindrum Lough.—Veins of thin, micaceous silicious flags can be raised in large sizes, capable of long bearings; mottled whitish-yellow, or pinkish colour. This stone appears capable of being sawn, and ought to be effective if used in fancy tiling.

Shanaghan—Ardara—near Shanaghan Lough, and other places in Loughros Promontory.—Vein of micaceous-silicious flags, from two inches or more to the thickness of roofing-slates, for which purpose they have been used; can be raised of considerable sizes, capable of long bearings.

Slieveleague—Carrick. Silicious flags.

CO. DUBLIN.

Ringsend glass.—For black, Irishtown sand; for clear, Antwerp sand; about 9*s*. per ton; or "Granuloid" (Portsmouth). The latter is a finely-granular quartz rock; it is supplied in blocks, costing about £1 per ton.

The following are the ingredients used in the manufacture of black and clear glass, respectively:—

Black Glass.	*Clear Glass.*
Irishtown sand.	Antwerp sand.
Waste lime (after manufacture of mineral waters).	Whiting (Glenarm).
Blue clay.	Soda ash.
Broken tiles.	Red lead.
Kelp waste (substitute for soda ash).	Manganese.
Rocksalt.	
Fluorspar.	

To make twenty gross of mineral water, or fifteen gross of brandy bottles, which is the quantity usually run from a furnace:—

18	cwt.	Antwerp sand.
$4\frac{1}{2}$	,,	chalk (or whiting).
2	,,	soda ash.
2	,,	sulphate of soda.
4	lbs.	red lead.
2	,,	arsenic.
2	,,	manganese.

About 1 ton of waste glass, such as broken window-glass.

The "Granuloid," when used, is thrown in, in the block, which rapidly melts down.

A rock very similar in aspect to the "Granuloid" occurs in the Howth Promontory, also in places in the counties Wicklow, Wexford, and elsewhere in Ireland.—(*R. Clarke.*)

LII.—ON A SEPARATING APPARATUS FOR USE WITH HEAVY FLUIDS. By PROFESSOR SOLLAS, LL.D. (Plate XIII., Fig. 1.)

[Read, January 19, 1887.]

Amongst the difficulties presented by the method of separating the mineral constituents of rocks with the aid of heavy fluids are two which the apparatus to be described fully overcomes. These are: first, that of removing the separated mineral from the apparatus; and next, that of effecting a rapid mixture of the fluid already in the tubes, and that which is added to reduce its density. The first is readily met, by using two tubes, which are united by a joint, with ground surfaces (fig. 1, *a*); the second, by closing the tubes with a stopcock at each end (*s*, *s'*), so that after each addition of dilute fluid the apparatus may be inverted. In using this apparatus, the heavy fluid having been introduced, the powdered mineral is added and allowed to separate. When the separation is complete, the stopcocks are all closed, and the two tubes separated from each other. If any mineral remains above the stopcock (*s'''*) it may be washed into the upper tube; the lower tube is then supported over a funnel containing a filter paper, and the contents allowed to run out by opening both stopcocks (*s'*, *s'''*). If any particles of the mineral remain behind adherent to the sides of the tube, they may be washed out by water. The tubes are then fitted together again, the stopcocks opened, and diluted fluid or water added; the terminal stopcocks at each end are then closed, and the tubes turned one and the other way up till perfect admixture is obtained; the whole is then left to settle till another separation is accomplished. To furnish the experimenter with approximate information as to the specific gravity of the liquid in the tubes, and to enable him to obtain approximately a desired specific gravity, the tubes are graduated so that the specific gravity of the fluid used at starting being known, and its volume also a measured volume of the diluent of known specific gravity can be added.

It may be useful if I here add a short account of the course of mechanical separation and associated operations, as carried out in

the Petrological Laboratory in Trinity College. The rock under examination is powdered till it all passes through the finest sieve usually to be found in a chemical laboratory; sufficient is taken from this for all purposes of chemical analysis; the remainder is placed in a tall beaker and washed with water. In this manner the fine dust or flour is removed, and one obtains a larger quantity of material, in relation to the quantity of rock pulverized, than if one employed only the powder, which will not pass through the finest sieve, with the additional advantage that it is of finer grain, and thus affords purer separations. No loss of time is involved in the use of finer powder; indeed, from the more perfect separation which it insures, there follows a slight gain in this direction. The fine powder is then dried in the water-oven and introduced into the separating-tube; the powder, first separated, is well washed with distilled water and dried, and its specific gravity taken by the aid of the modified Sprengel's tube, described in the succeeding Paper The powder, after removal from the Sprengel, is washed first with ether, and then with absolute alcohol, dried, and, if necessary, analysed; a known volume of water is then added to the mixture which remains in the separating-tube till another mineral commences to fall, and the course of procedure just described is repeated. From the quantity of water added a good idea, useful as a guide, is obtained as to the specific gravity of the fallen powder, and, in some cases, this will be sufficiently near the truth to render a more exact determination needless.

From experience I can recommend this course of procedure both for speed and accuracy.

LIII.—ON A MODIFICATION OF SPRENGEL'S APPARATUS FOR DETERMINING THE SPECIFIC GRAVITY OF SOLIDS. By PROF. SOLLAS, LL.D. (Plate XIII., Figs. 2–7.)

[Read, February 16, 1887.]

The simple and elegant specific gravity tube of Sprengel is not so well known among mineralogists as to render its description as a preliminary to indicating a slight modification of it unnecessary. It consists (fig. 2) of a small U-tube, drawn out at each end into a capillary. The capillary tubes are bent outwards, at right-angles to the limbs of the U-tube, and one of them grows wider (fig. 2, *e*), and the other narrower (fig. 2, *a*), as it recedes from the limb of the tube, with which it is continuous. A mark (*m*) for reference is etched at any point chosen on that capillary which expands outwards. This apparatus affords us a means of obtaining a definite volume of any fluid with an ease and accuracy which is not approached by any other direct method. The method of working is as follows:—The distally converging capillary (*a*) is immersed in the fluid with which it is desired to fill the apparatus, and by sucking at the end of the other capillary, the fluid naturally flows in. When it is filled beyond the mark on the expanding capillary, excess of fluid is drawn off by applying a piece of blotting-paper to the end of the converging capillary, the meniscus in the expanding capillary then slowly travels inwards, and when it reaches the fixed mark the volume of the fiuid is defined.

So far this apparatus has only been used in the case of fluid bodies; and even were it not possible to extend its application to solids, it might fairly be regarded as almost indispensable to the mineralogist for determining the densities of the heavy fluids used in the separation of the mineral constituents of rocks; but by a very simple modification it can be adapted to determine the densities of these minerals themselves when in a state of powder, as they necessarily always are when obtained separate by the use of heavy fluids. This modification consists in directing the distally expanding capillary vertically upwards, and enlarging it at its

termination into a funnel of a little larger diameter, at the brim, than that of the limbs of the U-tube (fig. 3).

The apparatus is first filled with water up to the fixed mark, and weighed; this weighing, after deduction of that of the tube itself, gives the weight of the volume of water required to fill the tube as defined by the mark. If it were possible to introduce now a weighed quantity of the powdered mineral, the density of which it is desired to ascertain, we should then simply have to draw off the excess of water till the fixed mark were reached, and the next weighing would give the weight of the water displaced by the mineral, and from this the specific gravity could be obtained at once.

This, indeed, is the principle employed; but the details are slightly modified. The surface-tension of water is so great that the powdered mineral, although well cleaned by the action upon it of the mercury and potassium iodide used in its separation, will not all sink through, but a small portion always floats as scum on the surface; it is therefore necessary to substitute some other fluid for water, and that which I have found succeed as well as any is the common paraffin used for burning in lamps. The specific gravity of this having been ascertained by means of the tube, the latter is filled with paraffin up to the brim of the funnel, and the powdered mineral introduced from a small weighing bottle. It rapidly falls through the paraffin, not a grain remaining on the surface. There is no difficulty in completely filling the limb of the tube from which the funnel proceeds, and thus results of accuracy can be obtained at a minimum expenditure of time and trouble. It may be useful to add a few suggestions on the filling and emptying of the apparatus. In filling, the tube should first be inverted (fig. 4), and care should be taken that the end of the immersed capillary does not accidentally emerge from the fluid. By sucking at the funnel end the liquid readily enters. When one limb has been completely filled up to the narrow constriction by which it is joined to the other the apparatus should be restored to the upright position (fig. 5), care being still exercised that the immersed capillary does not leave the fluid. The empty limb now fills by outflow from the full one, which is supplied by the siphoning action that takes place, now that it is in an upright position. By this method of filling air bubbles are

avoided, and the chance of the liquid (which may be corrosive or otherwise objectionable) entering the mouth is precluded. In emptying, when powdered mineral is present, the apparatus should be inverted in a small beaker of paraffin, and slightly inclined, so that none of the powder may find its way into the second limb. When all the powder is removed (and it falls out very rapidly), the paraffin is drained out, and the tube washed, first with ether, and finally with absolute alcohol.

The apparatus has the advantage of being very easily constructed. A piece of soft glass tube of convenient length, and any diameter, not too small nor too large (the operator can use his own judgment, within somewhat wide limits), is softened at one end, and enlarged into a funnel-shape (fig. 6), with a piece of hard, conically-pointed charcoal. A glass thread is then fused on to the edge of this, to enable the operator to draw out the narrow neck. This done, the other end is then drawn out into a capillary (fig. 7). The middle of the tube is next softened in a somewhat small blowpipe flame, drawn out, and at once bent, till the two halves of the tube are brought into parallelism. The terminal capillary is then bent into a position at right angles to the tube from which it proceeds, by holding a lighted lucifer-match under it, and allowing it to bend under its own weight. The two limbs of the tube should be sufficiently far apart to allow of their being cleaned on all sides.

LIV.—ANALYSIS OF THE BERYLS OF GLENCULLEN, CO. WICKLOW. By W. N. HARTLEY, F.R.S., Royal College of Science, Dublin.

[Read, March 23, 1887].

The beryls of Glencullen, Co. Dublin, described by Professor J. P. O'Reilly,[1] and by Mr. J. Joly, B.E.,[2] were analysed about twelve months since by Mr. J. B. Wise, a student in the Royal College of Science.

Analysis.—One grain of the mineral was fused with six parts of mixed potassium and sodium carbonates. After treatment with acids, it was found that a small portion of the substance remained unattacked. This was again fused, and it then showed a very decided green colour characteristic of manganese, possibly derived from the iolite contained in the mineral. The following are the data:—

	Analysis I. Ordinary Crystals. Per Cent.	Analysis II. "Weathered" Crystals. Per Cent.
SiO_2	47·47	54·27
Al_2O_3	32·49	27·23
BeO	11·29	10·50
CaO	2·60	1·40
FeO	3·13	2·88
MgO	0·41	0·47
Na_2O	0·46	0·47
K_2O	0·62	0·41
MnO	trace.	
H_2O	0·48	Not estimated.
	98·95	97·63
	Bases = 51·01	Bases = 43·36
	Silica = 47·47	Silica = 54·27

The specific gravity of the specimens represented by Analysis I. is 2·706 at 15·2° C.

[1] *Proceedings, R.D.S.*, vol. iv., p. 505.

[2] *Proceedings, R.D.S.*, *antea*, p. 48.

It will be observed that the weathered beryl contains what one might expect—a diminished proportion of bases and a correspondingly increased proportion of silica. According to the very careful research of C. A. Joy "On Glucinum and its Compounds," fusion of beryls with two parts of potassium carbonate can be successfully carried out.[1]

Fresenius states, "Native silicates of beryllia are completely decomposed by fusing with four parts of carbonate of soda and potassa."[2]

The proportion of alkaline carbonates necessary for the fusion of Glencullen beryls was found to be not less than six parts.

On referring to the composition of the beryls of Acworth, New Hampshire, which were the subject of Joy's research, it is to be noted that they contain more silica by one-third, and only one-half the quantity of alumina contained in the Glencullen beryls, thus:—

Composition of New Hampshire Beryls.

SiO_2 68·84, Al_2O_3 16·47, BeO 13·40 Fe_2O_3 1·7.

Those who are acquainted with the difference in behaviour of silicious minerals, when treated with alkaline carbonates, will acquiesce in the opinion that it is this high percentage of alumina which renders the beryls of Glencullen so difficult of fusion.

Taking into account the small proportion of bases present which are capable of replacing BeO, such as 2·6 per cent. CaO, 3·13 per cent. FeO, and calculating the molecular proportions of the other constituents, I have assigned to the mineral the following formula:—

$$2\,(Al_2O_3{\cdot}3\,SiO_2){\cdot}2\,(Be_2SiO_4){\cdot}BeO{\cdot}Al_2O_3;$$

or, differently expressed:—

$$2\,(Al_2Si_3O9){\cdot}2\,(Be_2SiO_4){\cdot}BeAl_2O_4.$$

From the point of view of their chemical composition these crystals are not beryls, but apparently a new mineral with a constitution lying between beryl and chrysoberyl, that is to say between a silicate of alumina and beryllia and an aluminate of beryllia.

[1] *American Journal of Science*, vol. xxxvi., p. 83.

[2] *Qualitative Analysis.* Ninth English Edition, 1876, p. 103.

Its mode of crystallization is unusual, being almost invariably radiated, though the crystals are hexagonal prisms.

In Mr. Joly's Paper it is shown that through some of the beryl crystals there were veins of felspar, and that near the base of a hexagonal prism there was an admixture of orthoclase and beryl. We may arrive at an approximation of the quantity of orthoclase admixed with the beryls which were the subject of the foregoing analyses, by taking into account the alkalies present, and assuming that they were not a part of the beryl, but constituents of the orthoclase; and, further, by taking into account the alumina present in beryls and in orthoclase.

Out of seventy-eight analyses of different specimens of orthoclase, the following numbers were taken as representing its average composition:—

SiO_2 65 per cent. Al_2O_3 19 per cent. Alkalies, 14 per cent.

The alkalies in beryl are 1·08 per cent., corresponding to a maximum of orthoclase of 7·7 per cent. While the alumina in the Glencullen beryls is 32·5 per cent., that in twenty other specimens is 18 per cent., or the same proportion as that in orthoclase. The difference in the proportion of silica in orthoclase and beryls is not great; in the latter mineral it amounts to 67 per cent., or 2 per cent. more than in orthoclase.

After the elimination of such quantities of bases and silica as may constitute an admixture of other minerals, we have to account for the presence of only 47·47 per cent. of silica, and the large proportion of 32·49 per cent. of alumina, that is to say, a deficiency of 21 per cent. of the former, and an excess of 16 per cent. of the latter; and the only way in which this can be done is by assigning to the beryls of Glencullen a formula which represents their constitution in the manner already described.

LV.—DEAL TIMBER IN THE LAKE BASINS AND PEAT BOGS OF NORTH-EAST DONEGAL. By G. H. KINAHAN, M.R.I.A.

[Read, April 20, 1887.]

Attention to the "corkers," or roots of trees, apparently in their natural positions in some of the lake basins, Co. Sligo, was directed by Mr. A. B. Wynne, at the last meeting of the Society, and he suggested that it was possible that once they may have been on a higher level on a substratum of peat, the latter being gradually removed by the wash or suction of the lake water, so that eventually they sank to their present position (*antea*, p. 499).

In the north-east of the barony of Kilmacrennan, Co. Donegal, "corkers" in the basins of the loughs and loughauns are very general; and for the last two years I have made them a special study, as it appears difficult to conceive how trees such as oaks and firs, especially the latter, which most abound, could have grown in places from which there is now no natural drainage.

In this portion of Donegal these loughs and loughauns are in more or less regular bowl, or saucer-like, depressions; while in some places there are shallow, oval, dish-shaped depressions, occupied by bog, in all of which deal or oak corkers are found *in situ*, that is, where they originally grew, below the present level of the natural drainage. Since the paper mentioned was read I have had opportunities of carefully noting the facts in connexion with some of the bogs and lakes which are now recorded.

No. I. *Bog in the Depression about Lough Aweel*, between Ramelton and Milford.—This lies in a large, irregular, oval, dish-shaped depression. To drain the bog, and make it available for turf-cutting, canals have been opened to the southward and westward, through the rim of drift margining the hollow; and at the greatest depth the bog has at present been cut, in the substratum, corkers of oak occur; while a little above these, in the peat, and extending horizontally to and on to the marginal drift rim, are corkers of deal. None of them seem to have been displaced, after they originally grew, until the bogs were cut.

No. II. *Glencarn Bog, or Mill-pond.*—This is situated a little

north-east of Ramelton, by the new road to Glenalla. At one time it was a boggy lake, and a bank seems to have been built across its *embouchure*, to utilize it as a mill-pond. Subsequently the peat in it was cut, and its level lowered by a canal. Now, the cut from the site of the old lake has been made so deep, that the tract, at will, can be entirely drained, so that it is a mill-pond in winter and a peat bog in summer, according as the sluice is down or up. When the waters are out it can be seen that some of the deal corkers in the area are in the position in which they originally grew, while others were evidently originally at a higher level in the peat, and were dropped down by the peat being cut away from under them. There are others also in a sedimentary peat; and although they look as if in their original natural positions, which some of the turf-cutters say they are, yet it seems to me quite possible that they may be "dropped corkers," around which recent sedimentary peat, the washing from the turf-banks and holes, may have accumulated.

Nos. III. and IV. *Carn and Thorn Lakes.*—These lie north of Glencarn Bog, in the vicinity of the road. In both, especially the latter, there are numerous deal corkers, most, if not all, of which are in their original positions. In connexion with these lake basins, it is possible that the drainage from them was stopped by the accumulation of peaty matter.

No. V. *Pollet Lough*, between Doagh Bog and Fanad Lighthouse, in the north-east portion of Fanad.—This loughaun is situated in a shallow, bowl-shaped depression. Numerous deal corkers, the majority evidently *in situ*. No apparent old site of a drainage vent.

No. VI. *Kindrum Lake.* In Fanad-within-the-Waters.—In the south-west arm of the lake is a cut-away bog, with deal corkers *in situ*. The stream from the lake is now a mill-race, the water of the lake being lowered in summer to allow the peat to be cut. The mill-race is cut in a stony drift, that never could have been brought into its present position by the lake waters.

No. VII. *Tawney Lough*, near the village—Numerous corkers in a saucer-shaped depression. They are evidently in their natural positions; while there are others that show the marks of the turf-cutters. The present drainage of the lake is a deep cut through the drift rim.

The selected lakes and bogs enumerated are sufficient to illustrate the general position of the corkers, and the situation in which they occur. From these examples it is evident that the majority are still in their natural positions. The general history of these different basins seems to be: as the turf was required, the canal from each lake basin was deeper; but when all the turf was cut the canals were neglected, and the sides caved in. This stopped the drainage, forming lakes on the sites of the old cut-away bogs. This in a measure may suggest how the drainage in old times was stopped; but at the same time it is not satisfactory, as it may be asked: by whom, or how, were cuts made through the margins of the hollows?

In connection with this subject the bogs margining the river Shannon may be referred to. Those above the rock barrier at Castleconnell (Falls of Donass) are in places lower than the sill of the Falls; but as I have in previous writings suggested, the drainage from the present basin of these bogs may have been south-west into the plain of Limerick, and thus independent of the Donass Falls. But in connection with the basin of Lough Derg, there are oak and deal corkers *in situ* in the bogs adjoining, far below the present level of the lake. This level I have also accounted for in a Paper "On the Basin of Lough Derg," as the drainage might have been southward into the Pollagh and Kilmastulla valley.

But when we go above Portumna there are hard questions, as the bogs along that section of the river and the Little Brosna are of great depth; and wherever they have been bottomed, oak corkers *in situ* have been found. How the land on which these grew could have had a surface drainage, eastward of the sill of limestone near Portland, it is hard to conjecture.

From the examples given it is quite evident that the majority of the corkers are now in their original position, and that the question of most importance is: How were these depressions drained to allow trees of deal and oak to grow there in former times?

Years ago I suggested that in places the flooding of hollows might be due to "beaver dams," but at the same time I pointed out that in the Irish glossaries there was no name for a beaver, the word in O'Reilly's Dictionary being taken from the Gallic. Since then, from a personal knowledge of beaver workings, I cannot say

that I see anything specially like them in Donegal, although some of the flats elsewhere may possibly have once been "beaver meadows." Under any circumstances, none of the cases in the county Donegal above enumerated could be due to such a cause.

From the places in which timber grew, and other circumstances, it is evident that before the advent of the bogs, Donegal must at one time have had a climate very similar to that now existing in the neighbourhood of the Gulf of St. Lawrence, Canada; and in connection with such a climate there must have been snow and ice, and during the thaws great slides of drift, which may have dammed up the lakes, as is the case in the present day in the province of Quebec and elsewhere in the Dominions. Some such solution might be suggested for the roots (corkers) of deal and oak being now found *in situ* in places from which, since the bogs began to grow till the present time, there has been no natural outlet for the drainage.

In connection with this subject the peculiarities of the timber found in Cloncarn bog, north of Treantagh, may be recorded. In Donegal, as seems to be usual elsewhere in the province of Ulster, the bogs are not at once cut to their full depth, but are "gone-over" in breasts of banks about three or four feet deep; so that in accordance with the depth of the peat accumulation the bog may be "gone-over" two, three, or more times before the final cutting that bottoms the bog. The upper cuttings or "gone-overs" of the Cloncarn bog are things of the past; but now they are bottoming out the bog, and the last cutting has given an appearance to it, similar to a bush-clearing in Canada—each tree stem standing three or four feet high. In Canada and the States, when clearing the bush, they cut off the tree between three and four feet from the ground, as a man can cut more trees in a day if he stands upright than if he stoops; while subsequently, after the land is tilled, it is easier to remove the roots, if they have a stem to act as a lever, than if they are cut close to the root. It can scarcely be supposed that the trees in the Cloncarn bog were similarly treated to those in a Canadian bush-clearing, as it seems evident that their present height is due to the floor of the last cutting-over of the bog, all sticks over that floor having been cut off. But even allowing this, they are peculiar as in general timber, that is, "bog stick," are found broken off and lying horizontal—the breaking off usually

being close to the corker, and rarely a few feet above it. This is the case, as far as my experience goes, not only elsewhere in Ireland, but also elsewhere in the county of Donegal, the trees having fallen before the bog grew, while here the bog must have grown around the standing trees. Furthermore, these trees must have been higher than as now represented, as it is possible they may have protruded, not only into the "going-over" before the last, but into higher strata; their original perpendicular height, however, cannot now be recorded, as all the cuttings of the bog but the last "going-over" was in the time of the ancestors of the present generation.

Besides this uncommon phenomenon, that is, *peat banking up standing timber*, there is another peculiarity to which I may refer—the spiral growth of many of the trees. This, however, is not confined to the timber in this bog, as I have remarked it in the county Donegal and elsewhere in Ireland. This I first remarked in the Cypress in Ontario, and it seems to be due to the hot suns in the Spring causing the bark on the south side of the stems to grow much quicker than on the cold north side; the trees that germinate early being thus affected, while the later ones are not. In these ancient Irish forests the same thing seems to have taken place, as in places many of the trees grew spiral, while adjoining ones grew straight. I do not know enough to be able to state if the timber which grows spiral is of a different species to that which has grown straight, but I would point out that in the bog of Kilpheak, north-west of Fox Hall, a large stick 20 yards long, 3 feet in diameter at the butt, and over a foot in diameter at top, and having its bark in ridges, just like a cog-wheel, was raised a few years ago, it having a quite different appearance to the sticks generally found. The timber had an appearance somewhat similar to the "yellow pine" now imported.

In the country north-west of Lake Superior, between Port Arthur and the Lake of the Woods, during the making of the Canadian North Pacific Railway, sections in peat now overgrown with timber were laid open. In them, as in the Irish bogs, timber had grown prior to the accumulation of the peat; but time did not allow of making special examinations. The fact, therefore, is only mentioned to show that there, as well as in Ireland, climatic or some other natural change will account for the records of the

different forest periods that occur, separated by a growth of peat. The time between the destruction of a forest and its re-growth may, in a measure, be learned in the province of Quebec. During the French and early English occupations all the low country between Quebec and Montreal was by the lumberers cleared of timber; now again it is a wood; not good marketable timber in the Canadian opinion, but as gross as the majority of firs to be found in the "Home country." These secondary woods are interesting, not only as to the re-growth of timber but also as to preserves for animal life; because as the country was cleared of its timber the wild animals retreated before the lumberers. Now, however, they have tried back, and in some of this re-grown bush, which is still considered the "old country," there is a better head of game than can be found even far up in the as yet undisturbed forests. Perhaps, however, the expression "tried back" is incorrect, as the animals more probably emigrated from their haunts in the as yet undisturbed north-east portion of the province.

In connection with our subject, the following information about the Fermanagh peat and timber, received since the paper was read from Mr. Thomas Plunkett, M.R.I.A., is of interest:—

To the west of Upper or South Lough Erne, on the hills, there is boulder drift, it at the bottom of the slopes being replaced or overlaid by brickclay. From these slopes the flats extend eastward in the river valleys to and beyond the lake; and from the canals opened in these flats it has been learned that in them there are five to six feet of alluvium (silt), above one to two feet of peat with timber, they resting on the glacial drift. The peat is flaky, and full of flagger-like plants (*Monagay turf* of Munster), and the timber is principally oak, some of the "sticks" being over forty feet long and five feet in diameter. This timber must have grown on a surface below the drainage outlets of the river flats west of Upper Lough Erne. In the low country east of the two lakes there are different saucer or dish-shaped lake basins, in which roots of trees *in situ* occur below their summer level: such as at Drumgay and the Mill lakes north of Enniskillen, and in two lakes in Castlecoole demesne.

To the eastward of Upper Lough Erne, on the sloping terrace round the top of Topped Mountain, there is a pagan cemetery, now covered by five or six feet of peat. On the flanks of the hill

there is sloping bog, and in the cooms, deep flat bog, and under the peat in the latter (from 10 to 25 feet deep) large roots *in situ* and sticks of deal and oak; one that was stepped being over 60 feet long and at the broken-off top over six inches in diameter. The floors of these flat bogs are saucer or dish-shaped basins, below the present drainage outlets. In the hills westward of Lough Erne there are also similar lakes to those in the low country, their basins being saucer-shaped, and having timber roots *in situ* below summer water-level.

Mr. Plunkett points out that the pagan cemetery now covered with peat, the trees on the hills of greater size than those which now grow on the low country, and the peat under the Upper Lough Erne flats, prove that the climate was, during the timber age, much drier and warmer than at present. This was succeeded by a wetter period, during which the woods on the flats became reedy marshes, while in the cooms in the hills and on their slopes mosses and such like grew; these peaty accumulations not only stopping the growth of the timber, but also destroying the woods and changing them into bogs. This was succeeded by still more rainy times, during which the flats of the tributary rivers of Upper Lough Erne were flooded by sheets of turbid water, the sill from which floods buried the "monagay turf," with its timbers, under the present overstratum of silt.

To account for the trees growing in the flats and hollows without drainage outlets, he suggests that during the period when there was little rain and great heat, all the rain that fell in the hollows was required by the trees, but if perchance there was a surplus, it was evaporated—this is known to take place in America at the present day, as in the "cedar swamps" and other "swamps" different kinds of trees grow luxuriantly in places without drainage outlets—also, when the rain became greater and the heat less, the moisture became excessive, generating the marshes in the flat and the peat in the hill, thus destroying the forests and burying the pagan cemetery.

LVI.—GRAVEL TERRACES; VALLEYS OF THE MOURNE, STRULE, AND FOYLE, COUNTIES TYRONE AND DONEGAL. By G. H. KINAHAN, M.R.I.A.

[Read, June 1, 1887.]

[The rivers of Tyrone have a multiplicity of names, as the main rivers and their tributaries, as often as they fork, are each given a new name: thus at Strabane the branches of the Foyle are called the Finn and the Mourne, while the latter, at every divide, has different names: the valley to which we would draw special attention is that now utilized by the railway from Omagh, by Strabane, to Derry, occupied principally by the Mourne.]

A traveller along the valley from Omagh to Strabane, and thence along the Foyle to Londonderry, may observe the series of terraces in the margining hill slopes, they disappearing in the vicinity of Derry; while if he goes north-westward into the valley of the Swilly he will not find any. This remarkable difference in the adjuncts of the Foyle and Swilly valleys has led to research and reflection.

In connection with Lough Swilly we find it among the loughs mentioned in the Annals as having "broken forth" during historical times. As so many loughs, both sea loughs and inland loughs, are mentioned as having "broken forth" at different times, there must be some reason for the records; the following suggestions, therefore, may not be out of place. As pointed out in the previous Paper (*ante*, p. 632), the climate of Ulster, before the later bogs began to grow, must have been somewhat similar to that of the country adjoining the St. Lawrence[1] at the present time. In this part of Canada there is great heat in summer and great cold in winter, with a small rainfall. Such climatic conditions in Ireland may have caused some of the present sea loughs to have become filled with ice; while some of the present lake basins (as suggested by Mr. Plunkett of Enniskillen, *ante*, p. 634), may have been hollows occupied by forests. A gradual amelioration of the climate ought, however, to affect the necessary changes; because

[1] The stone walls of huts similar to those now inhabited by the Lapps and other inhabitants of North Europe, as figured by Du Chaillu and by Nordenskjöld, in the voyage of the *Vega*, are not uncommon in places in the Co. Donegal.

as the winters become less cold, the summer less warm, and the rain-fall greater, the ice in the bays would gradually disappear, while as the evaporation was less, the hollows would become lakes, thus accounting for the "breaking forth" of the different inland and sea loughs.[1] This digression, although it may have a certain interest, does not seem to account for the great difference in the features of the marginal slopes of the valleys of Loughs Swilly and Foyle; but during a recent traverse of western Tyrone and Fermanagh it occurred to me that the phenomena in connection with the latter may possibly be explained by what is found at the present time in the river valleys of the "Foot Hills" of the Canadian Rockies.

Let us suppose that when the climatic conditions of Ulster were more or less similar to those of Canada at the present day, the Silurian hills (*Lower Old Red Sandstone type*) east of the plain of the Loughs Erne, and extending eastward nearly to Cookstown (which for convenience sake may be called the "Fintona mountains," after the town nearly in their centre), was a snow-field feeding small glaciers in the upper portion of each valley, while in each valley there was a river thick with silt and sand, each also being margined by gravel terraces. This may be seen at the present day in the upper portions of Bow and Belly rivers, Alberta, and in other river valleys east and west of the Canadian Rockies.

Many circumstances in connection with the surroundings of the "Fintona mountains" seem to support such suggestions. To the westward in the low country of the Loughs Erne the gravels seem to partake more of the character of glacial than marine accumulations; at the "divide," Pomeroy, in the central east and west valley, there is an excessive accumulation of sand and gravel, as at the "divides" of the river valleys in the Rockies between two glacial rivers or valleys; while the gravel terraces along the slopes and the flats of the Strule, Mourne, and Foyle valleys, if we allow for the subsequent modification due to meteoric denudations, are very similar to those of the Bow river, Alberta.

The genesis of these terraces in the valleys of the rivers of the

[1] Some lakes may have "broken forth," on account of a change in the level of the land, as I have elsewhere suggested, giving reasons in connexion with Galway Bay and Lough Corrib.

"Foot hills" has not as yet been satisfactorily explained; it is, however, evident that they are adjuncts of rivers from an alpine region. They die out as the lower open valley is reached, while elsewhere they are connected with greater or less flats. As their different characteristics are common both to the present Canadian and these ancient Irish river valleys, it seems not improbable that the terraces in both had a common origin.

It may be pointed out that the term "Esker gravel" seems to be getting very mixed. "Esker gravel"—proper—is the gravel due to the action of the "Esker sea" that once occupied the central plain of Ireland. Now, however, both in Ireland and America the term is being applied to all gravels if heaped up in ridges. This in one sense is correct, as all are "eskers," i.e. *ridges;* but the term ought to be restricted to marine gravels. This is not the case in the Co. Fermanagh, or in different places in the United States of America, where drift called eskers or kâms is evidently either of fluvial or glacial origin. Such, it would appear, was the origin of most of the gravels of Fermanagh and western Tyrone. But in south-east Tyrone it would appear as if the "Esker sea" came into some, at least, of the valleys, thus causing a blending of the Esker sea and the glacial gravels. A similar phenomenon may possibly also have taken place in the lower levels in the Co. Fermanagh, as the surface of Lower Lough Erne is about 150 feet over ordinary low water in Donegal Bay.

LVII.—ON THE INVERSION OF CENTROBARIC BODIES.

By THOMAS PRESTON, B.A.

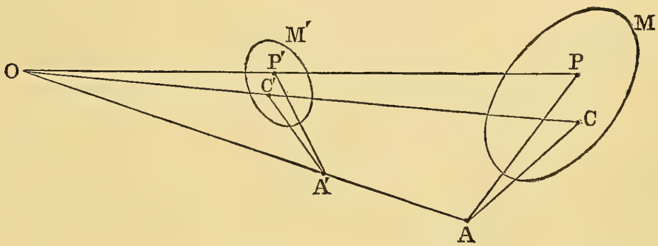
[Communicated by Professor G. F. Fitz Gerald.]

[Read, June 1, 1887.]

If M be any figure, and O a fixed origin, and if to each point P of M a corresponding point P' be taken on the radius vector OP, such that

$$OP \,.\, OP' = \text{a constant} = a^2, \tag{1}$$

a figure M' is obtained, which is termed the inverse of M.



Now if M be any continuous mass or any distribution of matter, and if at P' an element of mass dm' be placed, such that

$$dm' = \frac{a}{r}\, dm, \tag{2}$$

where dm is the element of mass at P, and $r = OP$, we obtain a distribution of matter M', the density ρ' of which at any point P' is connected with the density ρ of M at the corresponding point P, by the equation

$$\rho' = \left(\frac{a}{r'}\right)^5 \rho = \left(\frac{r}{a}\right)^5 \rho, \tag{3}$$

where $r' = OP'$. This equation follows at once from the relation $dv : dv' = r^6 : a^6$; the elements of volume at P and P' being dv and dv'.

Hence, if the density of M be uniform, the density at any point of M' will vary inversely as the *fifth power* of its distance from O. So also, if M be a uniform superficial distribution, M' will be a superficial distribution of density varying inversely as the *cube* of the distance from O.

It may be remarked that if, in equation (3), ρ varies inversely as the fifth power of r, then ρ' is uniform; that is, if M' be inverted from O the inverse mass will be of uniform density. However, if any other origin O' be taken, and if M' be inverted with respect to O' and a radius a', then the density ρ'' of this second derived distribution will be given by the equation

$$\rho'' = \left(\frac{O'P'}{a'}\right)^5 \rho' = \left(\frac{O'P'}{a'}\right)^5 \left(\frac{a}{OP'}\right)^5 \rho$$

$$= \left(\frac{a}{a'} \cdot \frac{O'O''}{P''O''}\right)^5 \rho,$$

where O'' is the inverse of O with respect to O'. Hence the density of M'', the inverse of M' with respect to O', varies inversely as the fifth power of the point from O'', the inverse of O'.

Or *a body, the density of which varies inversely as the fifth power of the distance from a fixed point inverts into a body of density, varying inversely as the fifth power of the distance from the inverse point.*

Again, for the total mass of M' we have

$$M' = \int dm' = \int \frac{a}{r}\, dm = a \int \frac{dm}{r} = a V_0, \tag{4}$$

where V_0 is the potential of the mass M at the origin O.

It is also easily seen that V, the potential of M at any point A, is connected with V', the potential of M' at the inverse point A', by the equation. (Thomson and Tait, *Natural Philosophy*, Part II. Art. 516).

$$V' = \frac{OA}{a} V. \tag{5}$$

Case of a Centrobaric Body.

If the mass M be centrobaric, that is, such that it attracts any other portion of matter as if all its mass were collected at C, its

centre of inertia, we have for the potential of M at A

$$V = \frac{M}{AC}.$$

Therefore, by equation (5) the potential V' of M' at A' is given by

$$V = \frac{OA}{a} \cdot \frac{M}{AC} = \frac{OC'}{A'C'} \cdot \frac{M}{a} = \frac{a . M}{A'C' . OC},$$

where C' is the inverse of C. But M/OC is the potential of M at O; therefore by (4) we have

$$V' = \frac{M'}{A'C'};$$

that is, the potential of M' at any point A' is the same as if all its mass were concentrated at C', the inverse of C. Hence we have the following

Theorem.

If any mass M be centrobaric, the inverse mass M' is also centrobaric, and the centre of mass of the latter is the inverse of the centre of mass of the former.

Thomson's Theorems.

Since a uniform sphere is a centrobaric body, attracting any external matter as if its mass were all concentrated at its centre, we have at once the following theorems of Sir W. Thomson:—

(1). A sphere, the density of which varies inversely as the distance from a fixed point O, attracts any other portion of matter as if its mass were all collected at a certain point, viz. the inverse of O with respect to the sphere.

[For the inverse of a uniform sphere is a sphere, the density of which varies inversely as the fifth power of the distance from the origin, and the inverse of its centre is the inverse of the origin with respect to the inverse sphere.]

(2). An infinitely thin shell, the density of which varies inversely as the cube of the distance from a fixed point O, attracts any other portion of matter as if the mass of the shell were all concentrated at a point, viz. the inverse of O with respect to the shell.

LVIII.—ON A MECHANICAL METHOD OF CONVERTING HOUR-ANGLE AND DECLINATION INTO ALTITUDE AND AZIMUTH, AND OF SOLVING OTHER PROBLEMS IN SPHERICAL TRIGONOMETRY. By A. A. RAMBAUT.

[Read, April 20, 1887.]

The principle of this instrument is by no means new. It was invented by De St. Rigaud, a Jesuit father, about the beginning of the seventeenth century, in the form of a sundial, which is described in the ninth edition of the *Encyclopædia Britannica.*

The application of the principle, however, to the problem of converting the place of a star from one set of co-ordinates to another has never, so far as I am aware, been pointed out.

In the spherical triangle, whose vertices are the pole, the zenith, and the star, and whose sides are, therefore, the complements of the latitude, the declination, and the altitude respectively, while its angles are the hour-angle, parallatic angle, and north azimuth, we have the following relations:—

$$\sin h = \sin \delta \sin \phi + \cos \delta \cos \phi \cos t, \qquad (1)$$

and

$$\sin \delta = \sin h \sin \phi + \cos h \cos \phi \cos A, \qquad (2)$$

in which h = altitude, A = azimuth,
δ = declination, t = hour-angle,
ϕ = latitude.

The construction due to De St. Rigaud, and on which the principle of this instrument is based, is as follows:—

With C as centre, and AC as radius (see fig. 1), describe a semicircle. Draw CF at right angles to AC. Make the angle FAC equal to the latitude. Draw FL at right angles to AF.

Now to find a star's altitude, being given its hour-angle and declination, make FAG equal to the declination, and ACD equal to the hour-angle. Draw DE at right angles to AC. With G as centre, and GA as radius, describe a circle cutting DE in I. Then the angle between GI and FC is the altitude.

To prove this, draw GK parallel to FC and GH, and IK at

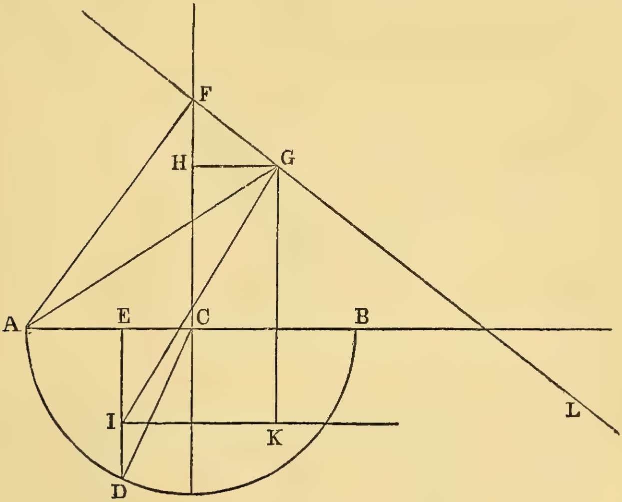


Fig. 1.

right angles to it. Then

$$\sin IGK = \frac{IK}{IG} = \frac{HG + EC}{AG}$$

$$= \frac{HG}{FG} \cdot \frac{FG}{AG} + \frac{EC}{CD} \cdot \frac{AC}{AF} \cdot \frac{AF}{AG}$$

$$= \sin \delta \sin \phi + \cos \delta \cos \phi \cos t.$$

Therefore $IGK = h$.

Equation (2) may be obtained from (1) by writing A and h for t and δ respectively, and *vice versa*. We thus see that if $FAG = h$, and $IGK = \delta$, then $ACD = A$.

The instrument which I have to describe consists of a circle M, graduated in hours and minutes on the inner side of the circumference, and in degrees on the outer side, to facilitate the readings of hour-angles and azimuths respectively. There is a straight edge corresponding to the line FL in figure 1 graduated, so as to read, at any point G (fig. 1), the angle between the lines AF and AG, and along this slides a piece NO which carries a pointer, and can be set at any required graduation.

Round a pivot X fixed in NO rotates a slotted piece R, which can be clamped at U to the disc V, the edge of which disc is graduated in degrees. A pointer Q is attached to the piece NO.

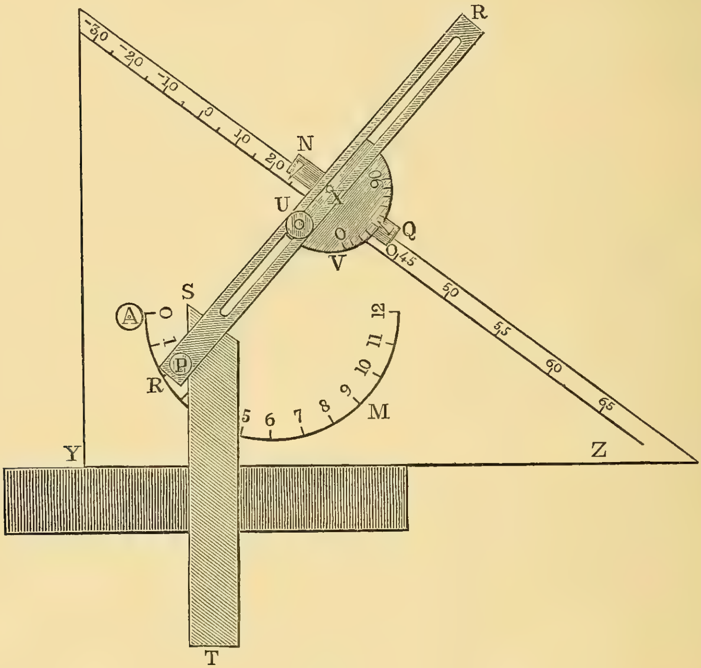


Fig. 2.

P is a cylindrical pin passing through R at right angles. Finally ST is a straight edge, which is always at right angles to YZ (or to AC, fig. 1), along which it slides.

Now in fig. 1 the angle between IG and GL is $\phi + h$. Accordingly, by causing the direction of the zero of the graduation on V (fig. 2) to make an angle ϕ with that of R, the pointer Q reads the altitude directly.

To find the Altitude of a star, therefore, it is necessary to set NO to the declination. Unclamp U, and bring P up to the point A (fig. 1). Clamp U. Slide ST along YZ till it cuts the circle M at the hour-angle. Rotate R till P touches ST. Then the pointer Q reads off the altitude.

To find the Azimuth, set NO to the altitude which we have just found. Unclamp U, and bring P up to the point A (fig. 1). Clamp U, and rotate R till Q reads the declination. Slide ST till it comes into contact with P, and its intersection with the circle M will then give the azimuth.

Since the section of the pin P is not a point, but a circle of considerable radius, in consequence of which ST is always too far to the right by the length of the radius of P, it is necessary to shift the circle M to the right by the same amount without altering its radius.

There are some other problems of minor interest which this instrument solves very easily.

For instance, the time of rising or setting of a heavenly body corrected, if necessary, for refraction, can be very easily obtained. For, since the horizontal refraction may be taken at 36′, it is only necessary to set NO to the declination of the body, and the pointer Q to $-36'$, and the point where ST cuts the circle M, when in contact with P, then gives the hour-angle of rising or setting.

To find the length of twilight on any given day, find the time of sunset as above. Then, by rotating the piece R till Q reads $-18°$, we get the hour-angle of the sun when 18° below the horizon, which gives the end of twilight.

For stars near the pole, or when a star is approaching the zenith, the rapid increase in the tangents of the declination and altitude will render the determination of the altitude or azimuth difficult, if not impossible.

LIX.—ON TWISTED COPPER WIRE. BY S. M. DIXON.

[Communicated by PROFESSOR G. F. FITZGERALD].

[Read, June 1, 1887.]

IF a piece of copper wire be given a great number of turns of permanent longitudinal twist, some of its physical properties are found to be greatly changed. It is no longer ductile, and it breaks instead of receiving a large permanent set, when it is distorted beyond its limit of elasticity.

The question naturally arises, How have the moduluses of elasticity been changed by this permanent twist? To answer this the following experiments were made:—

Some ordinary commercial copper wire, such as is used by bell-hangers, was taken. Its specific gravity was found to be 8·915, and from this its diameter was calculated to be ·0398 inch. This wire was then hung perpendicularly, the upper end being firmly fixed to a rigid support, and on the lower end was screwed a small vice, with a hook carrying a scale-pan, which weighed 1 lb. A weight of 4 lbs. was placed in this, the wire being thus almost completely freed from kinks. Young's modulus for this wire was then found to be 8,000,000 lbs. per square inch, and it could be loaded with 14 lbs. without any appreciable permanent set being produced, the wire being broken by $34\frac{1}{2}$ lbs. Several experiments were made with more of this wire, and the mean results are given in the Table at the end of this Paper.

Twenty-seven feet of the wire were then given 4900 turns of permanent longitudinal twist. The mode of twisting was as follows:—One end of the wire was clamped to the armature of a Gramme's magneto-electric machine, which was driven by two Grove's cells. The other end of the wire was fastened to a movable support. This support had to be moved slowly from the Gramme, as the wire increased in length as it was twisted. The number of turns given to the wire was counted by means of a velocimeter held on the Gramme. The first experiment showed that the specific gravity had diminished; but this result was found

to have been falsified by the air which adhered to the roughened surface of the wire, for on boiling the wire in water, the specific gravity then found was identical with that of the untwisted wire. The diameter of the wire was reduced to ·0382 inch.

On making experiments on this wire similar to those made on the ordinary wire, Young's modulus was found to have increased to 14,500,000, its breaking weight to 42 lbs., and $28\frac{1}{4}$ lbs. were necessary to produce a permanent set.

By drawing the first wire slowly by a weight, gradually increased to its breaking weight, Young's modulus became 15,000,000, which was practically the same value as the modulus of a piece of wire twisted till it broke.

To find the effect of twisting a wire which already had a permanent set, 14 feet of the drawn wire were given 3200 turns of permanent twist. Now, although it increased in length, as did the first wire, still its breaking weight was unaltered: Young's modulus was reduced to 11,500,000 lbs. per square inch, and 21 lbs. produced a permanent set.

The next experiment shows how much the limit of elasticity for bending was altered, Young's modulus being hardly changed. A piece of copper wire 12 inches long and $\frac{1}{10}$ inch diameter was given 180 turns of permanent twist in the lathe. This wire was then held horizontally by one end being clamped in a vice, while from the other was suspended a light pan for carrying weights. It was now found necessary to load the pan with 1 lb. to produce a permanent set. For a piece of ordinary wire of the same dimensions $\frac{1}{7}$ of this weight produced a permanent set. Yet in the case of these two wires there was very little difference in Young's modulus, the values of it being 12,500,000 and 12,000,000 lbs. per square inch respectively.

When a wire had once been given a permanent set by twisting, it was found that turning the wire in either direction had exactly the same effect. For example, three pieces of wire, each 4 feet long, broke when given 1430, 1380, and 1420 turns respectively; and when a piece of wire of the same length was first given 700 turns in one direction, it broke when twisted 696 times back in the contrary direction.

Wire ·0398 inch diameter, when given an average of 30 turns to an inch, was so brittle that it could not be wound on a

cylinder ·9 inch without breaking. The electrical resistance was found to have increased 8·3 per cent.

TABLE *giving the Mean Results of Experiments made on the Elasticity of Twisted Copper* :—

	Young's Modulus in millions of lbs. per sq. inch.	Weight producing permanent set, in lbs. per sq. inch.	Breaking weight in lbs. per square inch.
Ordinary Wire, . .	7·6	16,200	37,900
Ordinary Wire twisted, .	15·0	32,900	49,300
Ordinary Wire drawn by breaking weight,	15·0	—	37,900
Drawn Wire twisted, .	11·5	24,600	37,900

LX.—ON THE EFFECT OF CONTINENTAL LAND IN ALTERING THE LEVEL OF THE OCEAN. By EDWARD HULL, LL.D., F.R.S., &c., Director of the Geological Survey of Ireland.

[Read, March 23, 1887.]

When looking into the work of Professor Edward Suess, "Das Antlitz der Erde," [1] I was much surprised on lighting on a passage in which the author appears to adopt the view, that in some cases the level of the surface of the ocean along the margin of a continent may be as much as 1100 metres (or 3380 Parisian feet) above that of the surface along the shores of a mid-oceanic island; that is to say, so much further from the centre of the earth in the same parallel. This statement is founded on a formula adopted by Fischer [2] for the determination of the relative levels by means of oscillations of the daily second's pendulum at different stations along a continental coast, and a mid-oceanic island, to the effect that the amount in metres will be nearly 122 times the difference in the number of such oscillations. No special stations are mentioned; but he takes an example where the difference in the number of oscillations amounts to nine, giving the result of 1100 metres (in round numbers), above stated. In any case this is sufficiently startling, and, if correct, would be a great advance on the views generally held on this subject. If correct, even approximately, it is clear that large portions of continental lands are submerged which would otherwise be uncovered; while many islands owe their existence as such to the abnormal lowering of the ocean surface at a distance far removed from continents.

To some extent this is true; but the question arises, to what extent even in extreme cases.

As the length of the second's pendulum is proportionate to the

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[1] "Das Antlitz der Erde," 1st Abteil., p. 3 (1883).

[2] Fischer, "Untersuchungen über die Gestalt der Erde" (1868).

attraction of gravitation, and, therefore, with some corrections for local irregularities, to the distance from the centre of the earth, we have a means of ascertaining approximately the ocean-level at different points; and numerous observations of the length of the pendulum have been made both on continents and in islands. These have been collected by Airy in his elaborate article on "The Figure of the Earth," published in the *Encyclopædia Metropolitana*, from which I extract a few special examples. It will be observed that the length is mainly determined by the latitude. The observations were originally made by Sabine, Biot, and others, and are considered by Airy as "first-rate observations" in contradistinction to others, which he classes as "second-rate."[1]

Station.	Latitude.	Observed length of Second Pendulum in English inches.	Difference in Vibrations.
Spitzbergen,	79° 50′ N.	39·21469	+ 4·3
Hammerfest,	70 40	·19475	− 0·4
Stockholm,	59 21	·16541	+ 0·5
London,	51 31	·13929	− 0·2
Paris,	48 50	·12851	− 1·9
Bordeaux,	44 50	·11296	− 3·7
Toulon,	43 7	·10952	− 0·1
California (? Mexico),	21 30	·03829	− 6·0
Sandwich Islands,	20 52	·14690	+ 5·2
Jamaica,	17 56	·03503	− 0·8
Marian (or Marianne) Islands,	13 28	·03379	+ 6·8
Sierra Leone,	8 30	·01997	− 1·3
St. Thomas,[2]	0 25	·02074	+ 4·4
Ascension Island,	7 55 S.	·02363	+ 3·4

The name "California" in the above Table is clearly a mistake, if we go by the latitude, which is the more reliable of the two. California, as at present represented on our maps, does not reach so far south as 21° 30′ N. latitude. The cause of the decrease in the length of the second's pendulum, as we proceed from the poles towards the equator, is twofold—first, on account of the in-

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[1] Airy, "Figure of the Earth," *Encyclopædia Metropolitana*, vol. v., p. 229.

[2] Island in Gulf of Guinea.

creasing distance of bodies on the earth's surface from the centre of the earth, due to the oblate-spheroidal form of the earth itself; and, secondly, on account of the decrease of gravity due to the increasing centrifugal force depending on the velocity of the earth's rotation. Both these causes act in the same direction in lessening the gravity of bodies towards the equator; and, as a consequence, causing a decrease in the length of the second's pendulum. The total variation in the length between those at the equator and the poles amounts to 0·222 of an inch.[1]

From the data thus obtained we can determine the number of oscillations of a pendulum of the same length (or the same pendulum) on a continental and oceanic station; and, applying the formula stated by Suess, viz. 122 times the difference in the number of oscillations at two stations on (nearly) the same latitude, we obtain the result in mètres.

The results of the German physicists will probably surprise many who have been under the impression that the difference of level of the surface of the ocean, relatively to a geodetic surface, does not very much vary. Comparing the maximum and minimum results, it will be observed that the difference of level between California (or Mexico) and the Sandwich Islands amounts to no less than 4520 feet. The great rise in the ocean surface along the coast of California is accounted for by the extent and elevation of the mountain ranges along the American coast; and this notwithstanding the existence of the Gulf between the peninsula and the main land. The attractive influence of a mountain range near the coast is here clearly illustrated; and even more remarkable results might be expected, were a comparison instituted between stations on the coast of Peru and the Marquesas, or Society Islands, in the centre of the Pacific.[2]

Having called the attention of the President of the Royal Society, Professor G. G. Stokes, to the statement in Suess's work, in which his name appears, and requesting his views thereon, I have been favoured with the following reply, which is inserted by permission:—

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[1] Haughton, "Natural Philosophy."

[2] It is greatly to be desired that pendulum observations should be undertaken on the Peruvian coast. The Sandwich Islands would then answer for comparison.

"Lensfield Cottage, Cambridge,
"26th February, 1887.

"My dear Sir,—

"I am afraid you will think I have forgotten the question you asked me in your letter. It is not so. But I thought that before answering it I would look into Professor Suess's book, if I could find it. It is not, however, either in the University Library or in that of the Royal Society. But if I had found it I do not know that I should have been much the wiser; for, as you say, he gives no numerical data as to the dimensions of the supposed continent, nor does he specify what the continent actually is, if he is dealing with a real, not an ideal, continent.

"In a Paper 'On the Variation of Gravity at the Surface of the Earth,' which I wrote long ago, and which is published in the *Transactions of the Cambridge Philosophical Society*,[1] and in my collected Papers, of which as yet only two volumes have appeared, I showed that the effect of a continent would be to make a slight apparent diminution of gravity in continental stations as compared with detached oceanic islands. It operates in this way:—that the attraction of the land causes the surface of the sea level, the level surface, that is, which would be determined by a system of geodetic levelling carried from the coast inwards, to stand higher from the centre of the earth than it would have done had the place of the continent been occupied by ocean. The raising of the sea-level is greatest inland; but it is quite sensible, and even important, at the coast itself of the continent.

"How much the rising amounts to depends, of course, on the dimensions you attribute to the continent, and the height you give it above the undisturbed level of the sea. To take a numerical example, I suppose the case of a circular island or continent, whichever you please to call it, one thousand miles in diameter, and elevated a quarter of a mile above the sea-level. I suppose the depth of the ocean, in which this island is supposed to be placed, to be two miles. I make the usual suppositions as to the average density of the rocks, &c., in the neighbourhood of the earth's surface, and as to the mean density of the earth, which is fairly well ascertained. I find the elevation of the sea-level in the interior of the island, or continent (Australia), a good way from the coast, to be about

[1] Vol. viii. (1849), pp. 672–695.

four hundred feet. Of course in a great continent it might be considerably greater. This would cause an apparent diminution of gravity in continental stations—I mean, of course, in gravity as reduced by the usual methods to the level of the sea. In the first place, in reducing to the level of the sea we leave out of consideration the attraction of the stratum of earth between the actual sea-level and what the sea-level would have been if the continent had been away. As far as this goes, corrected gravity ought to appear too great. But in the second place, in reducing to the level of the sea, we reduce to a point further from the centre of the earth than we should have done if the sea-level had been unchanged ; and therefore in correcting we don't add enough to bring it up to what it would have been if ocean had been beneath us instead of land. On this account, therefore, gravity should appear too small—I mean reduced gravity. The two effects on apparent gravity are antagonistic, but the second is the stronger, so that on the whole gravity ought, *cæteris paribus*, to appear a little less on continents than on detached islands. Sabine and Airy have pointed out that such appears to be the result of observation ; but so far as I know, I was the first to point out that such a result ought to follow from the attraction of a continent by disturbing the sea-level.

"Far inland the thing could only be tested in those cases where the sea-level has been accurately determined by geodetic operations. We could not accordingly throw much light on the question by means of pendulum observations in Thibet.

"I am, dear sir,

"Yours very truly,

"G. G. STOKES.

"E. HULL, Esq., F. R. S.

"P.S.—You will find Airy's discussion in his article, 'Figure of the Earth,' in the *Encyclopædia Metropolitana*.

"An elevation of four hundred feet, even if there had been no intervening attraction to reduce the resulting diminution of gravity would only alter the number of vibrations per diem of a seconds pendulum by about one and a-half. Of course, apart from disturbance, the difference in the number per diem at two stations on the same parallel of latitude would be *nil*, and therefore the small difference of 1·5 would be infinity times that. I do not know what the term of comparison used by Fischer may be."

In the case, therefore, of a continental island a thousand miles across, and rising about 1320 feet above the sea-level, the effect of the attraction on the oceanic waters will be to raise the imaginary surface in the interior about 400 feet above a geodetically determined level; while the rise along the coast will be less. But Professor Stokes very truly adds, the effect in the case of a great continent might be considerably greater. Where, for instance, we have a continent such as that of South America, from 2000 to 3000 miles across, rising from an ocean of an average depth of 15,000 feet, and bounded by the giant mountain range of the Andes, with an average level of 12,000 to 16,000 feet, who can say what the effect of the mutual attraction of this mass of land on the surface of the Pacific Ocean may amount to? Certainly considerably more than in the hypothetical case of Professor Stokes. In certain cases the effect of this rise, in altering the superficial areas of land and sea would be very considerable; but, owing to the comparatively steep gradients of the coast and mountain slopes, as well as of the submerged portions along the Pacific borders, the effect in diminishing the area of submerged marginal lands is less apparent than if the gradients were more gentle.

The same observations apply, in a less degree, to North America.

The effect of such an arrangement of the configuration of ocean and continent as is presented along the western sea-boards of the American continents, where extensive mountain ranges and elevated plateaus stretch for thousands of miles along the borders of a deep ocean, must be much greater than is generally supposed. The orographical characters of these continents, and their relations to the oceanic waters, may be regarded as affording the required conditions for bringing about a maximum result in the elevation of the ocean-surface. The most powerful attractive force is that exercised by the lands immediately adjoining the sea-board; and as we recede from this line inland the attractive force necessarily diminishes as the square of the distance. Hence the conditions required for the maximum effect are found when there is an accumulation of solid matter in the form of mountain ranges close to the coast-line; and this is exactly what happens in the case of the American continents. Judging from the elevations and breadth of the range of the Andes of Peru, and Bolivia, in South

America, and of the Rocky Mountains of Mexico, in the northern continent, it may be assumed that the ocean surface reaches a higher level along these portions of the coast than elsewhere.

The general result of our inquiries seems to be, that the form of a geodetic section of the earth, taken parallel to the equator, and at successive intervals both to the north and south of that line, would give curves of ever-varying irregularity according to the position of land and water. That there must be a very important variation from the mean ellipsoidal form along the western margin of the two Americas it is impossible to doubt. Bulgings to a smaller extent may be inferred along the coast-lines. It is probable that these equalize one another over the whole surface of the globe; and, as compared with the diameter of the globe, they are unimportant. Nevertheless, the effect of the elevation and depression of the ocean surface must have been felt throughout all geological time. The effect of the uprising of mountain chains, or the submersion of lands, in altering the ocean level, becomes an important element in the discussion of questions connected with the distribution of land and sea both in the present and in past geologic periods.

I propose to continue the discussion of this subject on a future occasion, the present Paper being only of a preliminary character.

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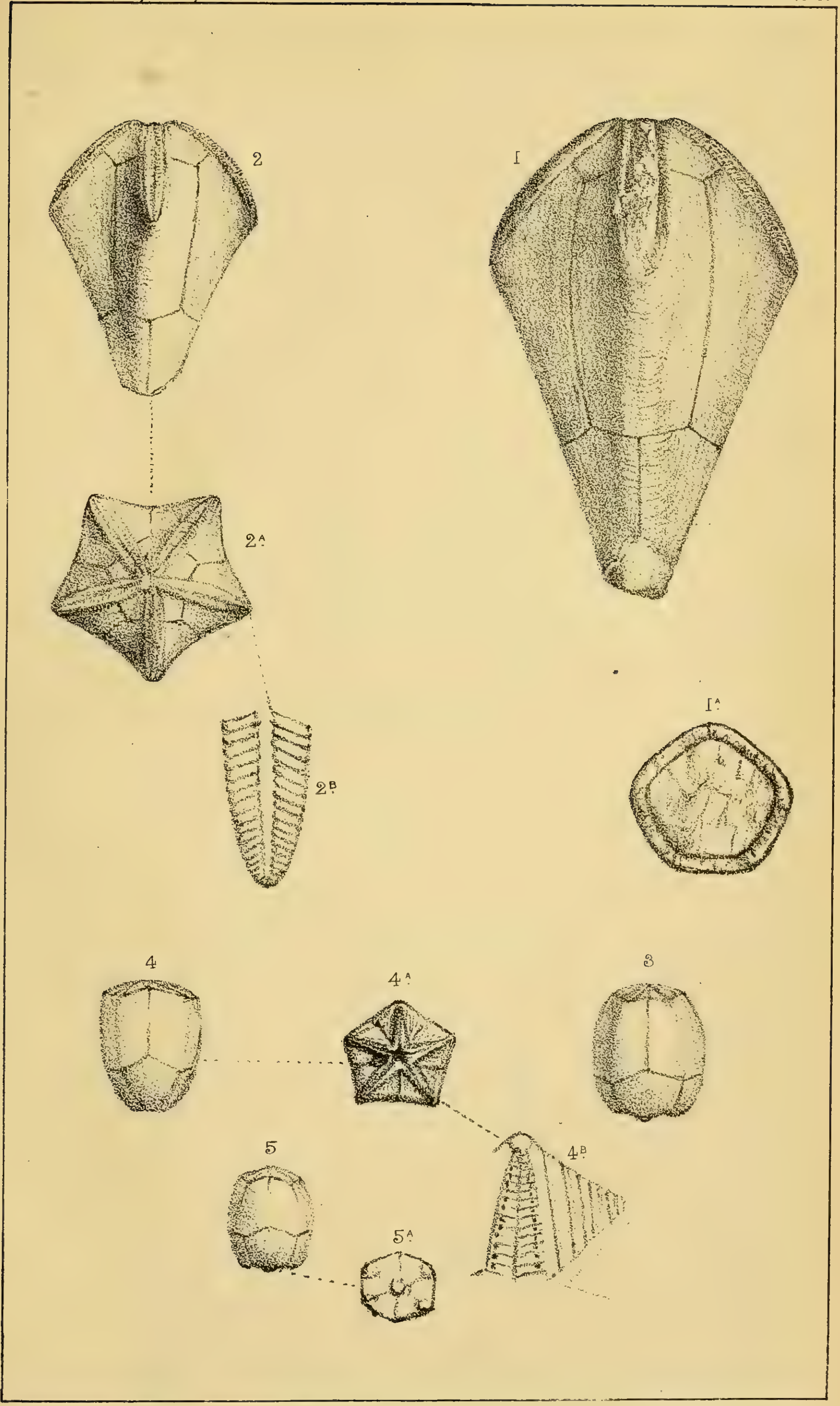

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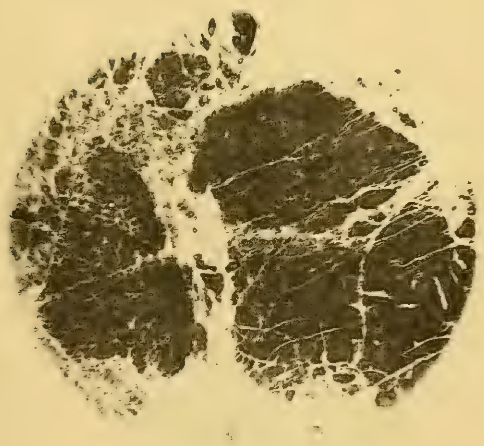
Fig. 1.

Veins of Felspar through Beryl. Section parallel to axis of hexagonal prism. Light polarized. (X 18 diameters.)

Fig. 2.



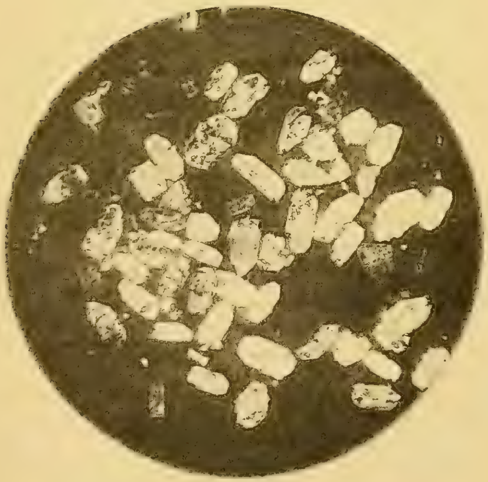
Broken down Beryl. Section near base of hexagonal prism of mixed Beryl and Orthoclase. Polarized light. (X 18 diameters.)

Photo. from Nature, Photo-Ptd. by FORSTER & CO., Ltd., DUBLIN

Fig. 3.

Group of Iolite crystals removed from cavities in mixed Beryl and Orthoclase. Light Polarized. (X 18 diameters.)

Fig. 4.



Iolite in situ, showlng marking of Orthoclase.

Fig. 5.

Photo from Nature,

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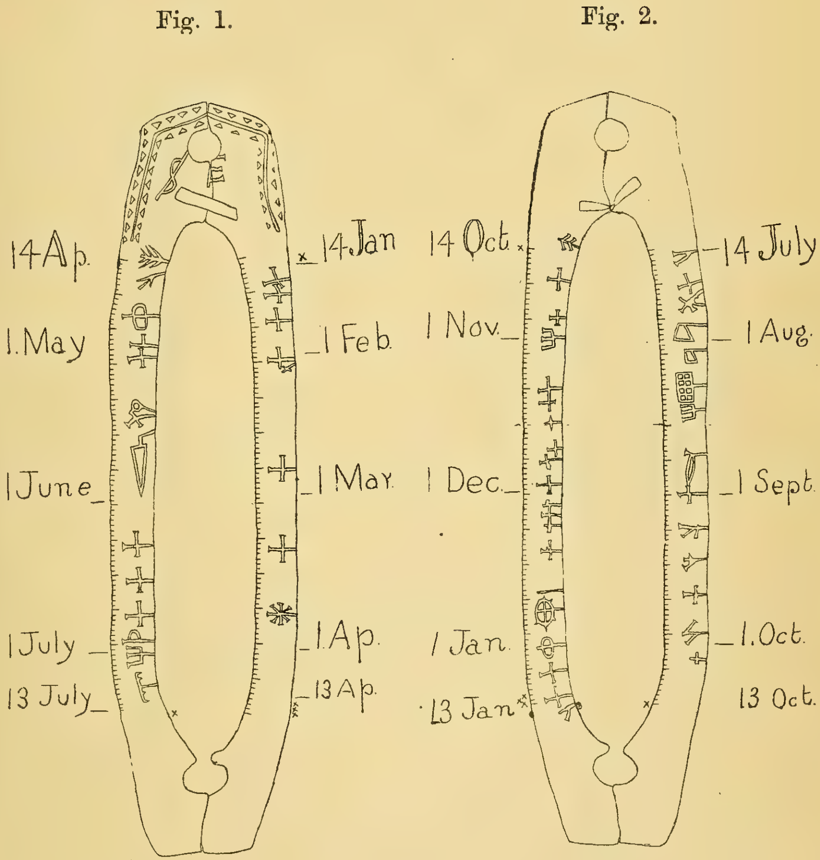

A CLOGG ALMANACK.

In the Science and Art Museum, Dublin.

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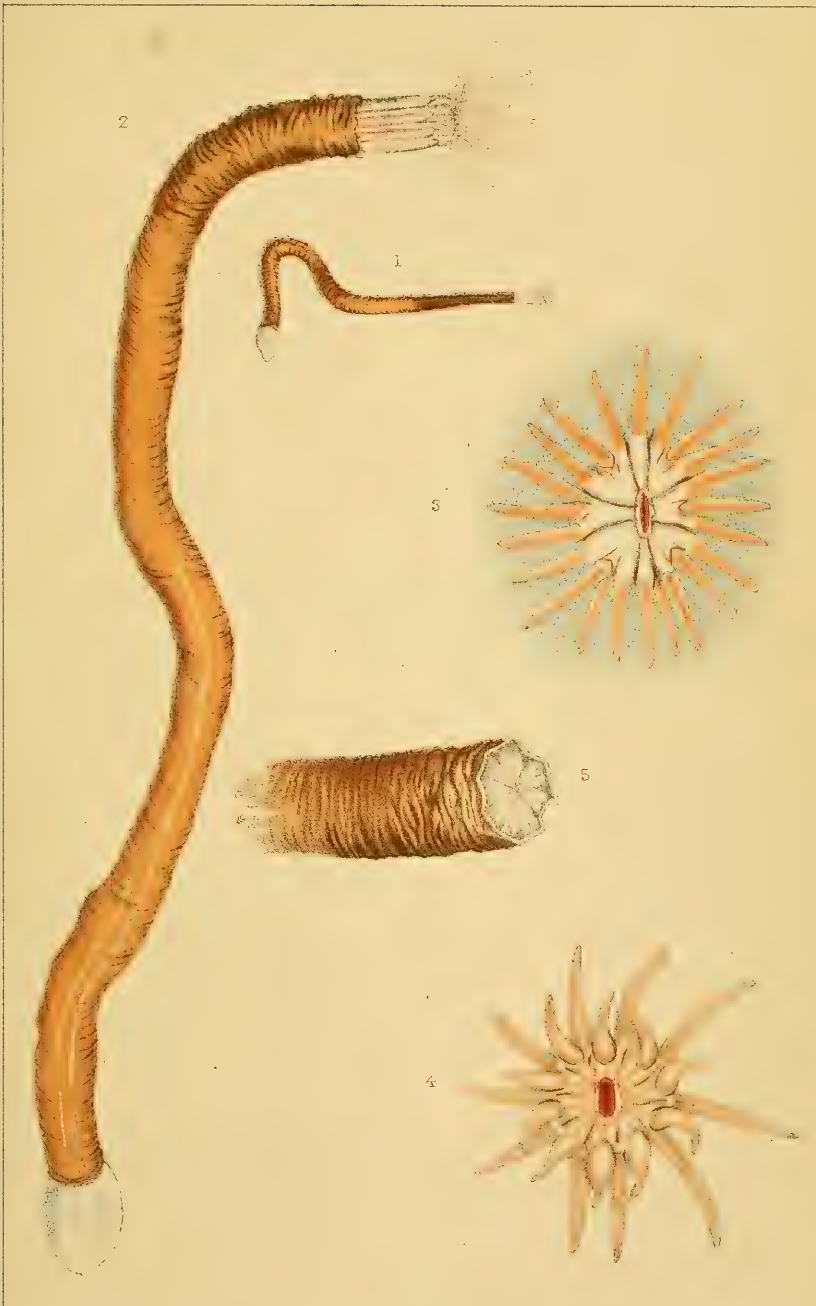

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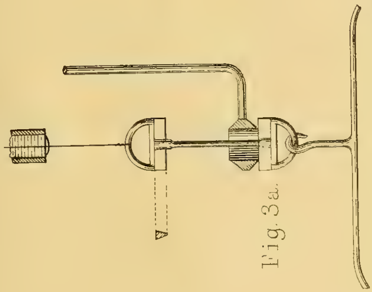


Fig. 3a.

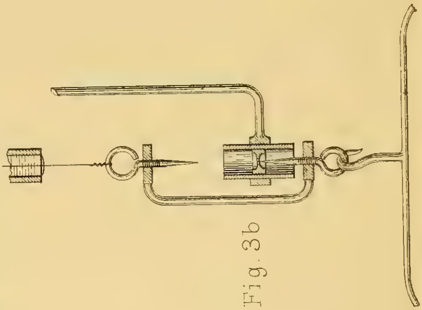
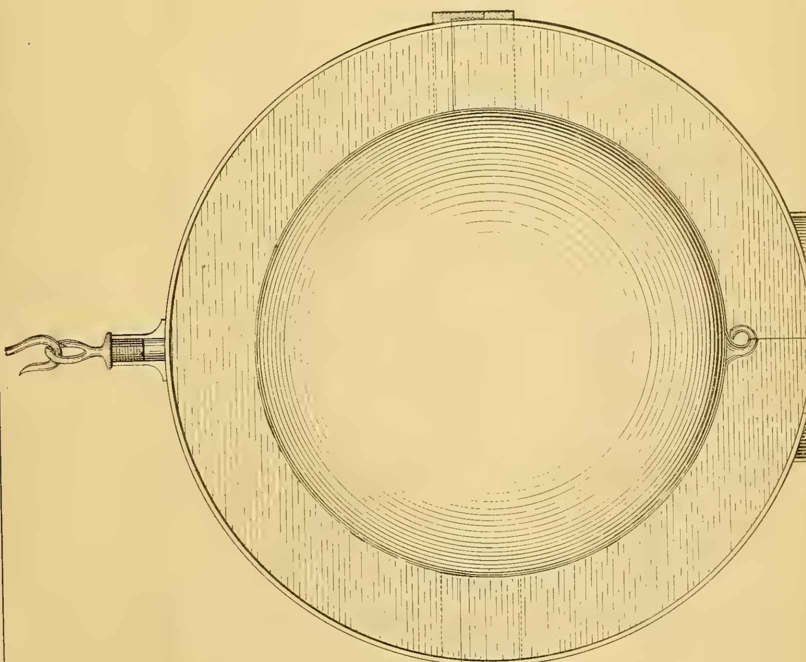


Fig. 3b



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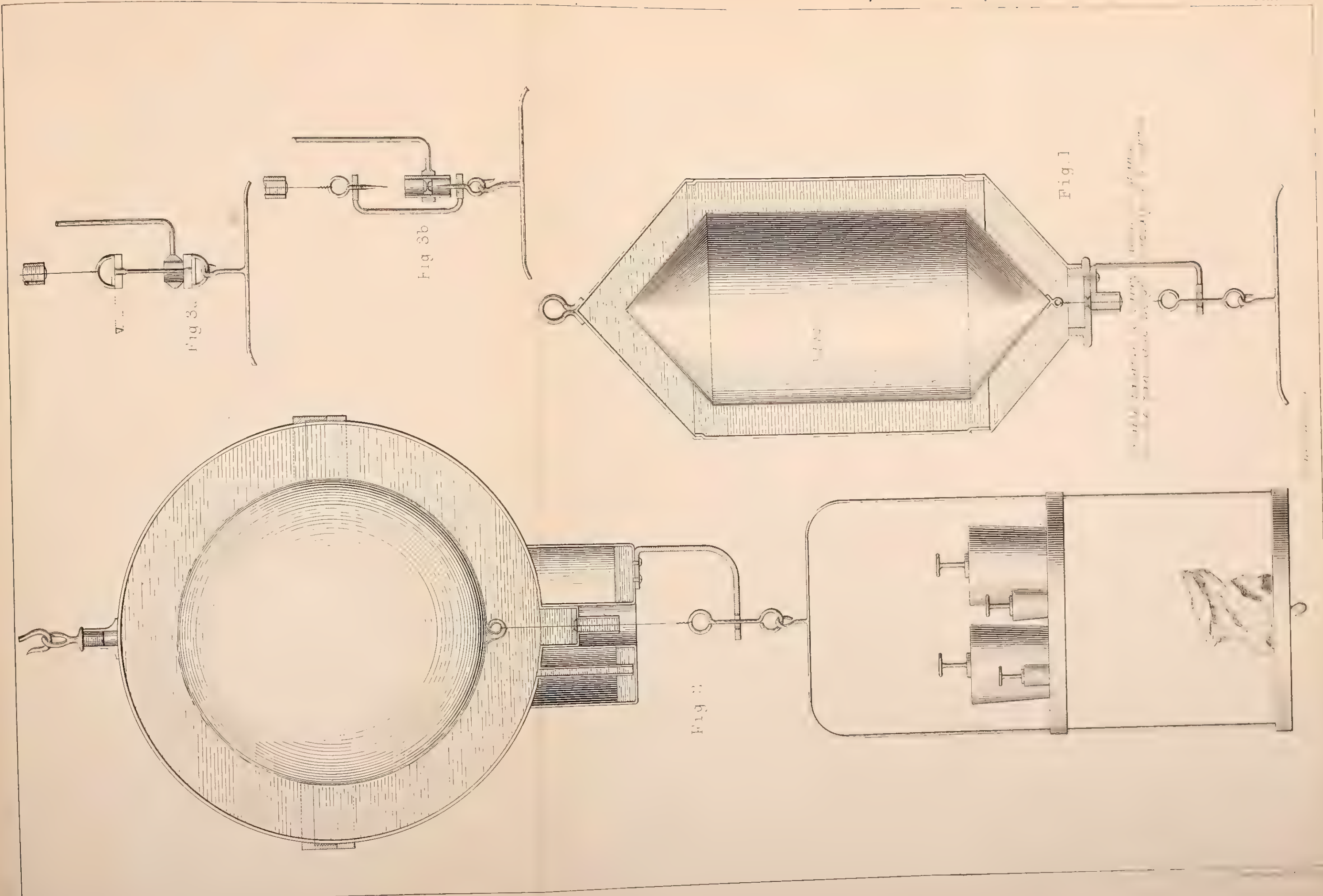

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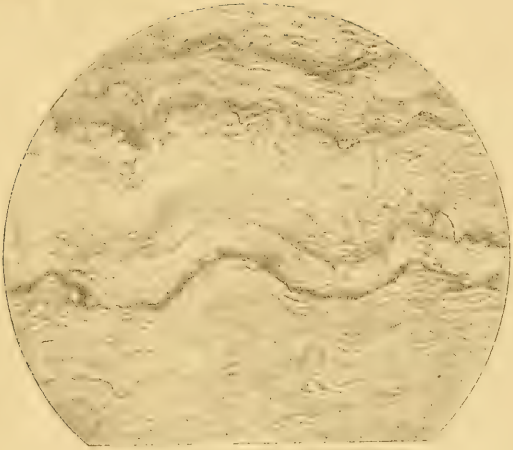

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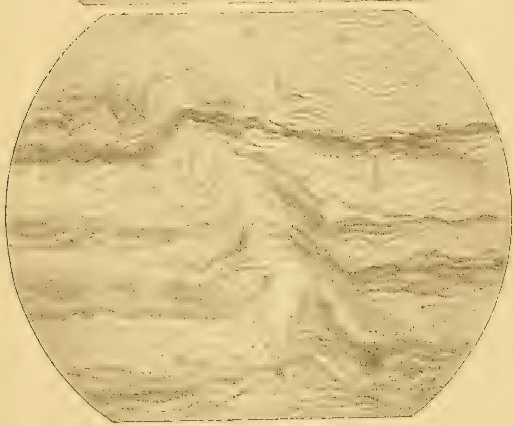

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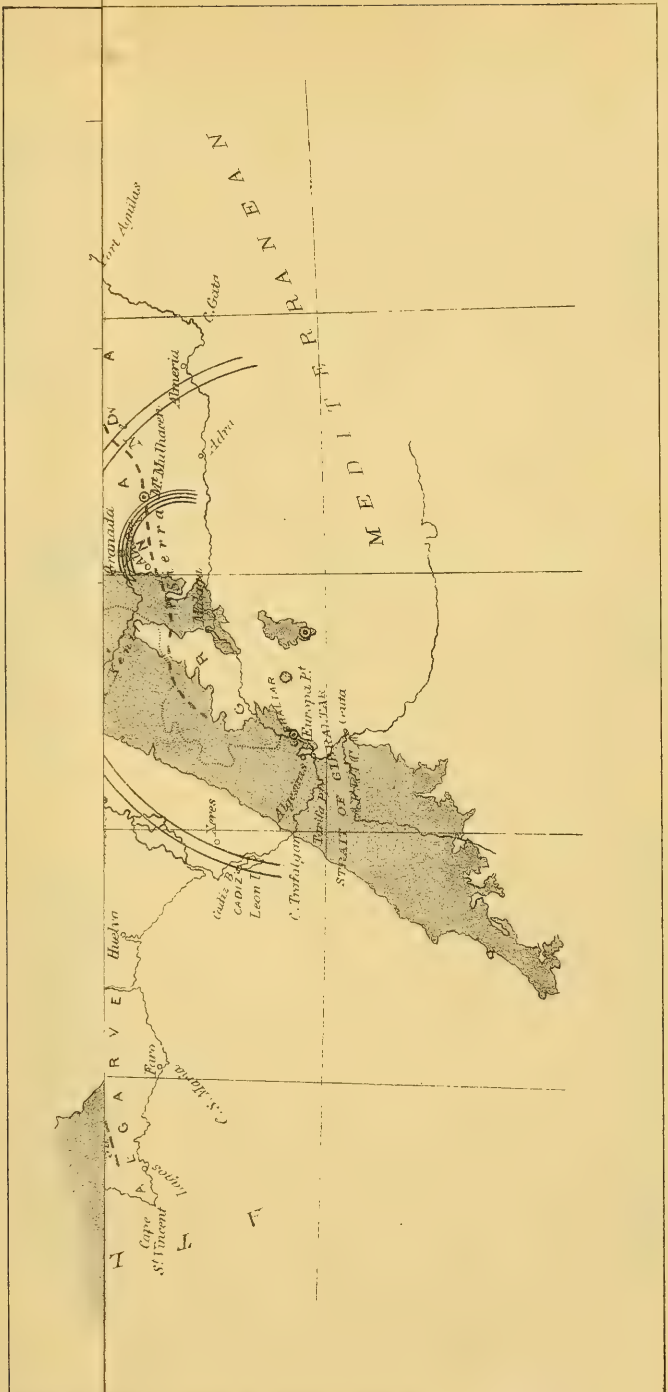

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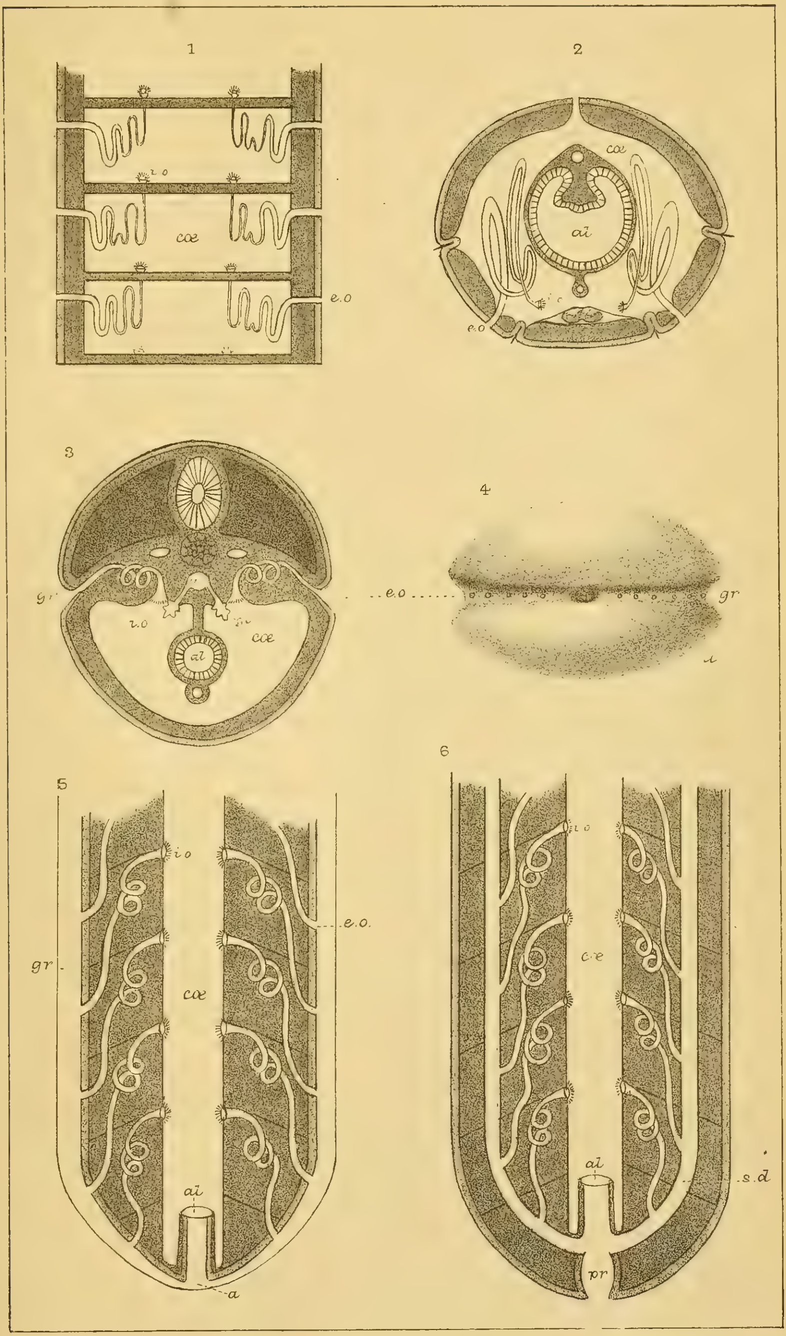

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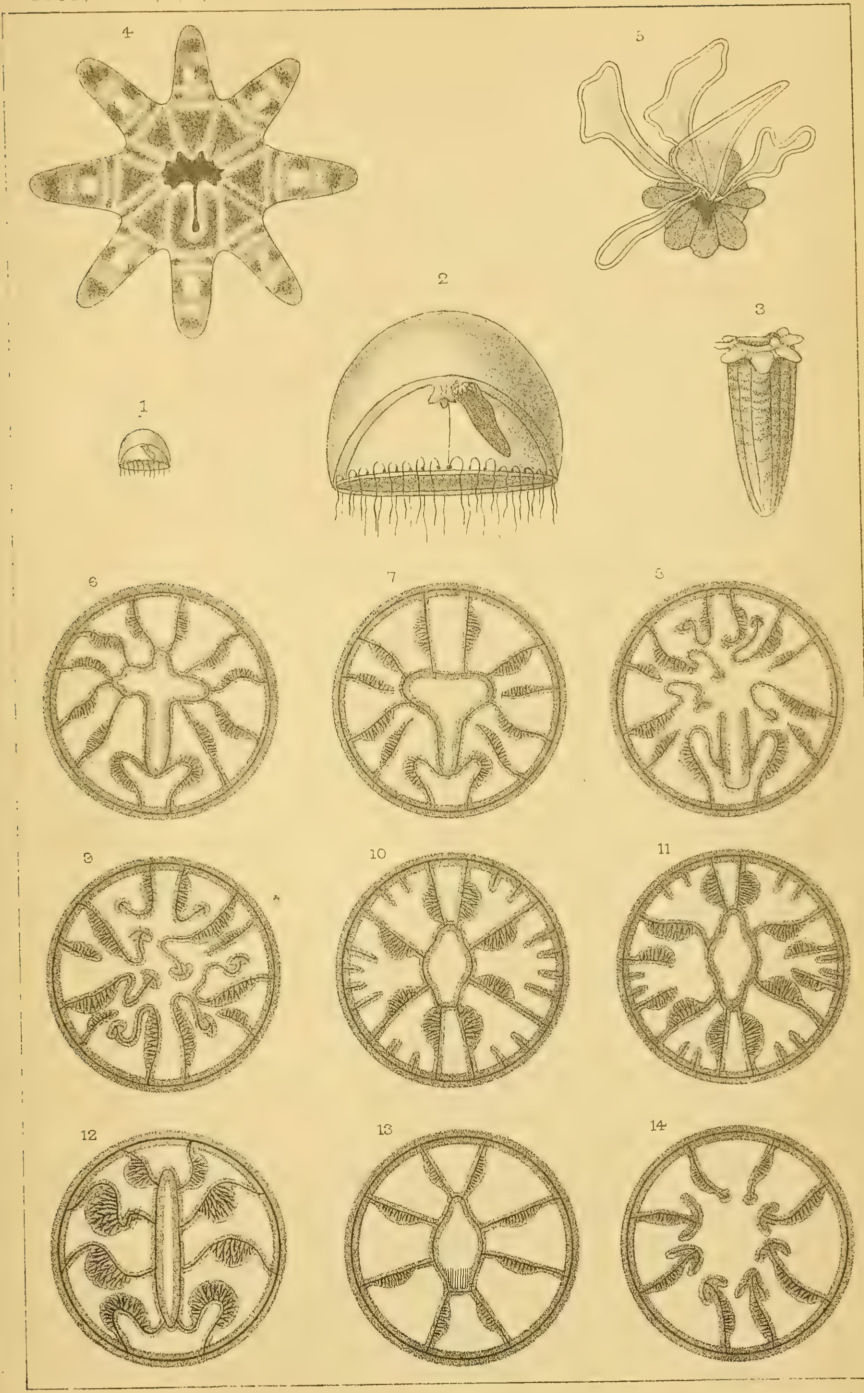

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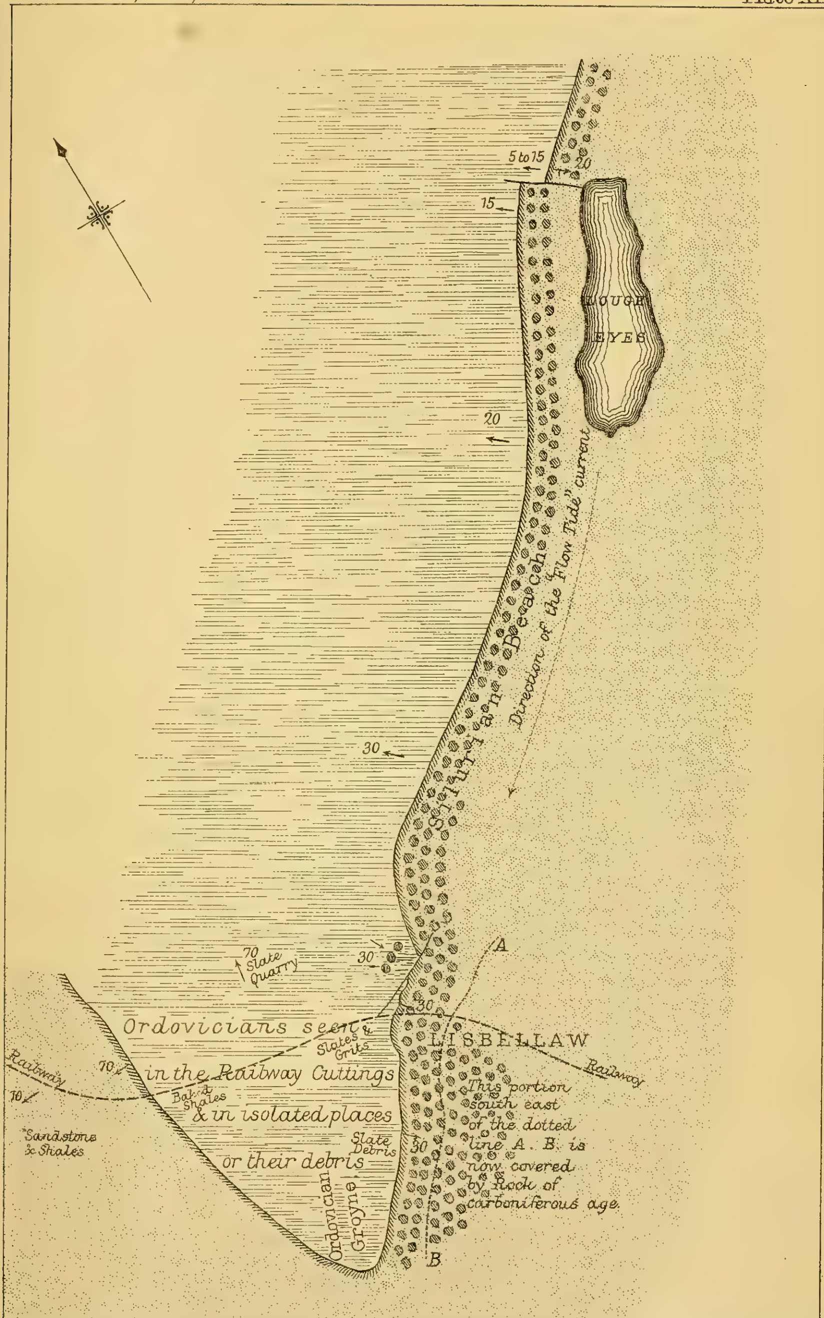

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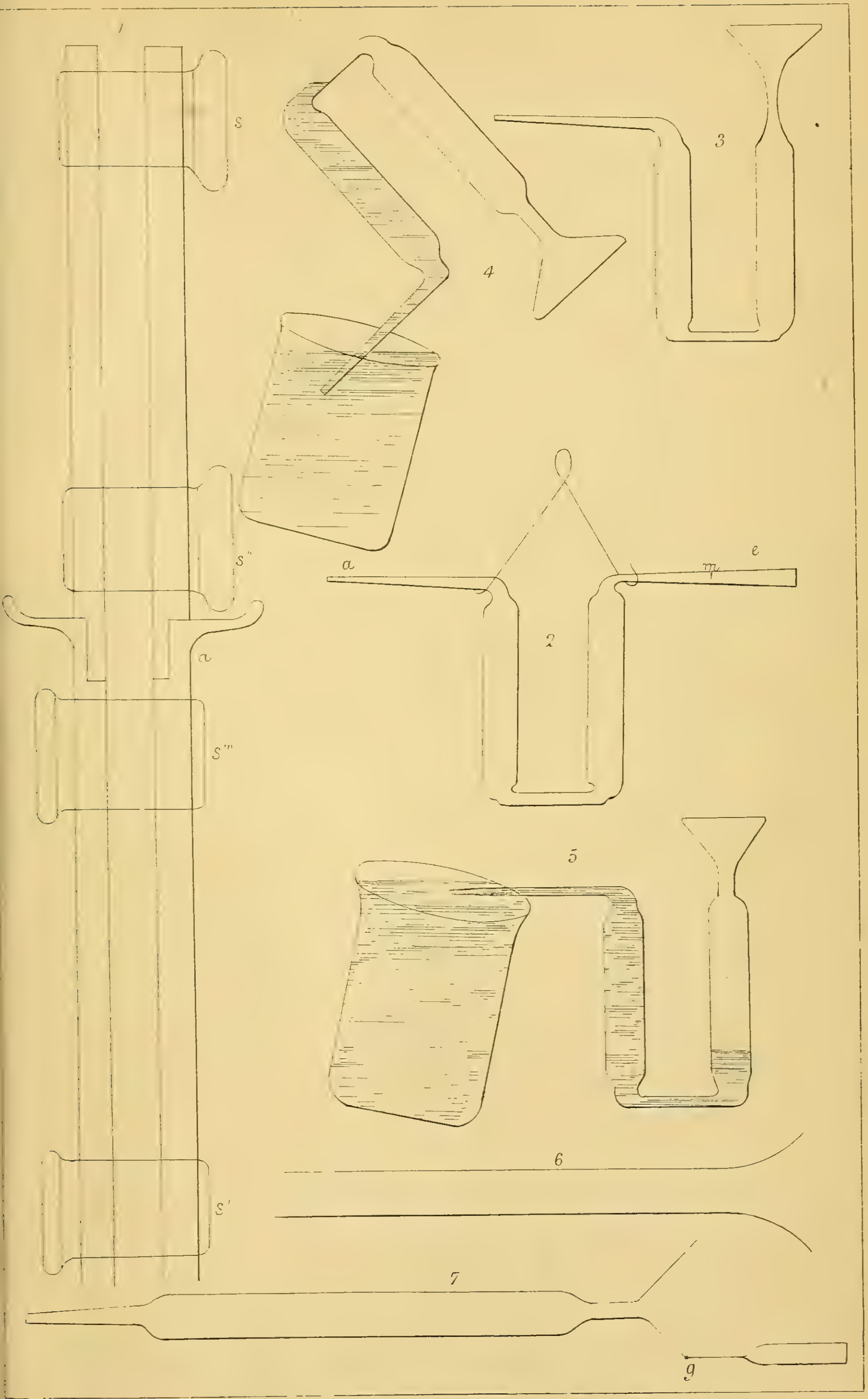

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